Volume 19 Number 5

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

MAY, 1935

METAMORPHISM OF ORGANIC SEDIMENTS AND DERIVED OILS[1]

DAVID WHITE[2]
Washington, D.C.

ABSTRACT

Responding to the comments and criticisms offered since the publication of his paper, "Some Relations in Origin Between Coal and Petroleum," embodying the so-called "carbon-ratio theory," published 20 years ago, the author discusses the progressive regional metamorphism of the mother rocks of coal and oil, which advances from stage to stage with each advance in orogenic movement, the periods of advance being, he holds, those of most active oil generation and of metamorphism represented by cracking, with probable underground enrichment or hydrogenation of oil in confinement. The extinction zone, or the oil "dead line," at which in their evolution the oils have become so light that they are no longer liquid at surface temperature and atmospheric pressure, is found in many regions to fall in a zone narrower than at first defined and represents a carbonization (indicated by fixed carbon, pure coal basis) between 61 and 63 of the associated coals in those regions. Oil is believed to have been generated in several cycles, in all cases probably under dynamic influence. Relations of regional metamorphism to the "law of Hilt," which applies to oils as well as to coal, are discussed, together with sources of error, in defining the extinction zone.

INTRODUCTION

Since the publication, twenty years ago, of my paper, "Some Relations in Origin Between Coal and Petroleum,"[3] in the *Journal* of the Washington Academy of Sciences, I have made little attempt to discuss the comments thereon, whether favorable or adverse. It seemed to me that the main proposals put forward in the paper were either already so fully established or so plainly in the process of

[1] Manuscript received, February 18, 1935. Read before the Association at the Wichita meeting, March 22, 1935, by Frank Rinker Clark. Published by permission of the director of the United States Geological Survey.

[2] United States Geological Survey. The author died, February 7, 1935.

[3] David White, "Some Relations in Origin Between Coal and Petroleum," *Jour. Washington Acad. Sci.*, Vol. 5 (March 19, 1915), pp. 189–212.

demonstration that the doubts raised would settle themselves in the course of time if merely "left to ride." Largely this has proved true, both of the actual or tangible troubles and of those less tangible, some of which were founded on too careless reading or on misunderstanding or misstatement by some other reader.

In brief, the principal proposals set forth in the paper, not all of which originated with me, are the following.

1. According to the organic theory of origin, oils and the associated natural hydrocarbon gases, as well as coals, originate in chemically organic débris buried as sediment. The mother substances from which, chiefly, oils are derived, consist predominantly of the remains of aquatic life, plant and animal, of low forms composing typically a sapropelic plankton or colloidal saprocol mixture, relatively fatty or rich in hydrogenous high-volatile substances and low in oxygen. The organic mother rock of coal, on the other hand, is overwhelmingly composed of vascular, terrestrial plant débris embracing a great variety of plant products, in general characterized by high-oxygen carbohydrates, the deposits being rich in humic products and relatively low in volatile matter.

2. The mother débris of both groups, which may intergrade according to the environment of deposition, is subject to fungal and bacterial action at the time of burial, with consequent selective decomposition, which may greatly affect the chemical composition of the residual microdetritus, the progress of the microbian agents being dependent on the proportions of the various plant compounds and the conditions of deposition, including the amount of oxygen that is available or can be made available, the degree of conservation of toxic products, and other conditions.

3. Following and even overlapping the apparently relatively short period of biochemical change attending its sedimentation is a period in which the organic débris is subject to incipient metamorphism on a regional scale, synchronous, though in general more sensitively and earlier expressed, with the progressive metamorphism of the associated inorganic sediments.

4. The progressive metamorphism of the mother substances, whether of coal or of oil, is chemically indicated most conspicuously by the so-called "carbonization," effectively the "devolatilization," of the mother rocks, and by the progressive loss of water, oxygen, and hydrogen (also nitrogen), in the course of which the organic deposit may be found at any stage (rank) in the successive changes from a peat, or its equivalent sapropel, to the anthracite rank, or to graphite, graphitic shale, or graphitic schist.

5. The regional progressive metamorphism is further marked physically by progressive compression, induration, cleavage, and schistosity; changes of refraction, luster, and color; and changes in behavior, such as coking.

6. In the case of coal, we have at all times to do with the solid residue—finally graphitic—of the organic sediment remaining *in situ* in the ground; in the case of petroleum, asphalt, paraffine, and related hydrocarbon products, we have to do with matters generated from the mother substances, but volatile and fugitive from the progressively altered residues, and themselves subject to alteration or reorganization, with the formation of lighter products and carbonization of residues, under metamorphic influences.

7. The chief physical factors—i.e., the principal metamorphic factors—participating in the production of coal, gas, and oil are pressure, temperature, and time. Pressure works miracles with hydrocarbons as well as other commodities in the laboratories, besides being a source of temperature. Temperature on a regional scale, including geothermal gradient and heat of chemical reaction, is normally relatively low where oil is generated, and is exchangeable to undetermined extents for time especially, as well as for pressure. Time is of geologic length, and is substitutable in part also for pressure. Other factors of lesser value are depth of burial, involving conductivity of cover and geothermal gradient, as well as weight of loading; heat of chemical reactions underground, including reactions of associated chemicals to the surrounding physical influences; catalysts, colloids, enzymes, reactions with inorganic substances, et cetera.

Emphasizing the dominant importance of pressure in the metamorphism of the organic mother rocks, I stressed particularly the rôle of competency in assuring greater compressive alteration in competent areas, in contrast to folding or faulting, which compensate or neutralize the thrust. Regions of competency and high carbonization, in contrast with adjacent regions of weakness and consequent folding, were cited in proof that "disturbance," or folding of the strata, was not a *cause* of the metamorphism but an *effect* by means of which more advanced alteration was averted. Some of my critics have not duly regarded this very important distinction.

Finally, after illustrating the progressive carbonization of the coals of the Appalachian Trough, the Eastern Interior Basin, and the Mid-Continent and Gulf Coast regions, contours being drawn to show the advance in the fixed carbon (ash-, moisture- and sulphur-free basis), I superposed the respective oil-field maps on which the Baumé gravity of the oil in different fields had been contoured. This showed

(*a*) that in general the oils of lowest Baumé rank were found in association with or closely underlying formations, generally young, in which coals, if present, were of the very low rank of brown lignite; (*b*) that oils of somewhat higher rank were characteristically associated with formations carrying black lignites or so-called "subbituminous coals"; (*c*) that oils of still higher rank attended a metamorphic advance corresponding to low-volatile bituminous coals; (*d*) that oils of the highest rank attended a stage of carbonization marked by a fixed carbon of 59 to 61 per cent in the coals; and (*e*) that in the zone characterized by 62 to 68 per cent of fixed carbon of the coals (if present) oils were not found in commercial amounts, though small amounts of white oil, kerosene or gasoline, might locally and rarely be present. The last-mentioned zone, later defined as between 62 and 65 per cent of fixed carbon, has been called the "dead line," and I have recently termed it the "extinction zone."[4] Natural-gas fields, I early pointed out, may extend into areas of much more advanced metamorphism.

Unfortunately, a rule of the Washington Academy of Sciences against the printing of folded plates caused the reduction of my map nearly to the point of illegibility. The great thrust faults and their compensation effects were partly obliterated.[5] The map, again greatly reduced, was republished by D. T. Day.[6]

It is impossible to give due consideration to all the criticisms and queries that have been raised without republication of the greater part of the paper. Many of them have already answered themselves. I will, therefore, in the following pages, take account primarily of the more important and still open questions. Fortunately, W. Taylor Thom, in the chapter on the "Carbon-Ratio Theory" in *Problems of Petroleum Geology* (pp. 69–95), has summarized most, at least, of the American criticisms, so that they may be readily consulted.

REGIONAL PROGRESSIVE METAMORPHISM OF MOTHER ROCKS OF OIL AND COAL

Probably incredulity regarding my conclusions, especially among Old World geologists, centers in greatest volume on the basic question

[4] *Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Congress (Recess), on H. Res. 441*, Part II (1934), p. 910.

[5] The distribution of the *Journal* was so small that not long after publication of my article the entire reserve of the issue containing it, as well as my 200 separates, were exhausted in response to applications. Consequently, my paper is known to most geologists only through the writings, not always accurately presenting my proposals, of others.

[6] D. T. Day, *Handbook of the Petroleum Industry*, 1922, p. 10.

of the regional progressive metamorphism of organic sediments—their evolution in fact—from the peaty to the graphitic stage, the conditions under which it takes place, the criteria distinguishing its progress, and the consequent implications respecting the origin and evolution of oils.

A circumstantial as well as most obvious proof of the progressive regional metamorphism of the organic sediments is that, while it becomes apparent at an earlier stage—in the "infra-red," so to speak —it progresses, with all its features (dehydration, cleavage, chemical change, etc.), simultaneously and in exactly the same direction as the regional progressive metamorphism of the inorganic sediments, as was pointed out by H. D. Rogers as long ago as 1843. By going from region to region it may be followed all the way from the lowest rank of lignite, merely a deeply buried peat, to anthracite.

In my papers I have stressed more and more strongly the importance of pressure—mainly "horizontal" thrust pressure—as an effective factor in incipient metamorphism, a view that has, in general, gained in weight also with the physical geologists.

The dominant value of pressure in conjunction with the competency of the rocks engaged is shown particularly well in the northwest-southeast section across the anthracite region of Pennsylvania; in the bituminous coal fields in western Pennsylvania and Ohio; in western Maryland; in the Pocahontas-New River-Kanawha region of Virginia and West Virginia; in northern Arkansas;[7] in the Trinidad coal field of Colorado; in western Wyoming; and in eastern Montana.

If the areas and belts of higher carbonization owed the loss of volatile matter to "disturbance," cleavage, or fracture of the beds, as suggested by many authors, or if the loss were due to the easier escape of volatile matter through the coarser and more porous rocks, or along the axes and flanks of anticlines, as is still insisted by some of my colleagues, the carbonization should advance toward the west in the Southern and Western anthracite fields, where the sections remain thick and the rocks are coarser, instead of advancing eastward as it does; the coals flanking the Viaduct, Laurel Hill, and Chestnut Ridge arches should be higher in fixed carbon than the identical beds where they lie flat, east of these folds; and the outcropping measures along or on the Pocahontas, Hunter Valley, Pine Mountain, Oliver Springs, Birmingham, and Choctaw overthrusts, should be higher in fixed carbon than the beds immediately west—the direction of thrust—instead of being lower, on account of the neutralizing and

[7] David White, "The Progressive Regional Carbonization of Coals," *Amer. Inst. Min. Met. Eng., Trans.* (February, 1925).

compensating effects of the great thrust movements involving overlap displacements, some of them several miles in width.[8] The occurrence of oil in the fenster near Rose Hill, in southwestern Virginia, just east of the coal field, described by Butts,[9] should cause no surprise, in view of the drop in carbonization due to the overthrusting in that region.

Mapping the eastward progressive carbonization of the Lower Kittanning coal bed between the Allegheny River and the "Allegheny Front" (the frontal border of the bituminous coal region) in central Pennsylvania, Miss Stadnichenko[10] found an increase from 58.6 per cent of fixed carbon on the west to 84.7 per cent on the east, about 50 miles distant, in the Johnstown-Windber district, which lies abreast of an apron of competent strata projecting eastward into the Valley region of folded older Paleozoic rocks. On the other hand, while this area illustrates the effects of pressure in *competent* strata, the effect of lack of competency—that is, of compensation of the thrust pressure by overthrusts—is seen in the region on the north, where the carbonization of the same coal bed, without change of components or of paleontologic constitution, is reversed and drops about 20 per cent as the coals pass behind overthrusts near the border of the coal field. In the region of Pennsylvania described by Miss Stadnichenko, with detailed studies of the constituents of the coal bed, no change in the accompanying flora offers explanation of the chemical changes of the coal.

It is important to observe that each of the associated coals in the group containing the Lower Kittanning coal changes in approximately identical percentages through the same distance and direction as the Lower Kittanning. Also the identical coal, or one at the same horizon and paleontologically similar to the Lower Kittanning bed, is present in the Broad Top field and the Bernice (semianthracite) and anthracite basins, where the coal progressively changes from a semianthracite on the west to the hardest anthracite in the less folded area at the east. Similarly, the same bed may be traced from the Georges Creek Basin in western Maryland (fixed carbon 82 per cent), to Zanesville, Ohio (56 per cent).

[8] See the maps of the Paleozoic regions of Virginia recently issued by the State Geological Survey, and map of Mineral Resources of the Tennessee River Basin, compiled from published sources by the U. S. Geological Survey, 1933.

[9] Charles Butts, "Oil in Lee County, Virginia," *Dept. of Interior Mem. for the Press* (July 3, 1923).

[10] Taisia Stadnichenko, "Progressive Regional Metamorphism of the Lower Kittanning Coal Bed of Western Pennsylvania," *Econ. Geol.*, Vol. 29, No. 6 (1934), pp. 511–43.

The Lower Kittanning coal is fully as near the basal Pennsylvanian unconformity at Windber, where the fixed carbon is 83 per cent, as at Kittanning, or along the Ohio River, where it is reached by shaft. The Sewell coal gains 12 per cent of volatile matter in passing westward along New River, and the Helena coal group, in Alabama, increases from 25 to 40 per cent in passing from east to west.

There are many areas in Europe, including the South Wales coal field, in which the metamorphic effects of sustained thrust on relatively competent beds are plainly seen, though most of the illustrative areas are small, on account of the more complex systems of folding of the European continent and the many buried lines of weakness inherited from earlier movements.

It is the contention of some geologists, on the other hand, that greater heat, as well as heavier loading, has been experienced by the beds in the deeper parts of the large deep synclines, or synclinoria, than on the flanks or crests of the great anticlines, and that the carbonization should therefore be greatest in the structural deeps. Others argue that the beds on the crests of the broad arches or folds have been subjected at closer quarters and more effectively to greater geothermal temperature of magmatic origin and hence that the carbonization should be higher toward the crests of the arches. The discussion of these proposals involves the so-called "law of Hilt."

RELATION OF "LAW OF HILT" TO REGIONAL METAMORPHISM

The "law of Hilt," which was proposed to cover the progressive carbonization of the coals downward in the vertical section, relates to no distinct principle, no special phenomena. It concerns merely the increase of metamorphism downward in the deeper rocks. It reflects the same causes and the same effects as metamorphism in the horizontal directions. It has no status as a "law" except in the minds of those who do not accept the metamorphic evolution of coals and other organic sediments as an established fact.

Too little attention has been paid to the downward carbonization gradient in normal vertical sections of different coal fields, though its manifestation in the metamorphism of oils is the subject of increasing study. The carbonization gradient is seen to vary somewhat widely in different basins, and it commonly varies, sometimes with reversals, in parts of the same vertical column. The anomalies in a single vertical column are readily found to result from the presence of abnormally fatty or of fusainous coals. The variations in different basins are most probably due to the relative participation of the different metamorphic factors, and the conditions existing in

the particular area and at the depth of the coal at the time of increase in metamorphism. Apparently the variations in rate in the column due to ingredient matter tend to decrease and disappear as the coals enter the semibituminous and semianthracitic ranks, as I have elsewhere noted.[11]

Naturally, on a steep anticline with close outcrops the percentages of fixed carbon in the lowest coals on both sides should be and generally are higher than those in the successively younger coals on either side of the axis.[12] But if the anticline is in a zone of rapid advance in regional carbonization, or if it is a broad arch, each of the coals, including the lowest, will generally be found to have higher fixed carbon on the side of greater metamorphism than on the other. In fact, if low dips carry the outcrop far back from the axis on that side, the fixed carbon of the stratigraphically high coal may be greater than that of the lowest coal on the other side, a fact illustrated in many fields. It is for this reason that in areas of bituminous coal of moderately low rank, far from the source of the horizontal stress and where the structure as well as the fixed carbon is variable within narrow limits, as on the west side of the Appalachian coal field in Ohio, the lower coals outcropping near the margin of the field are higher in fixed carbon than the overlying coals that crop out somewhat farther east.

The downward progress in the metamorphism of coal was first emphasized, I believe, by H. D. Rogers[13] in 1843. It is more interesting than the lateral progress, because it brings more tangibly into view the separate metamorphic factors and offers some basis for the integration of their relative values under varying conditions. It has to do with the time factor in a specific or priority sense; more significantly, it reflects the geothermal gradient; it involves depth of burial, weight and heat conductivity of load, orogenic history and recency of orogenic movement, amount of uplift or depression, rate and time of erosion, stress mechanics, and relations to magma masses.

Though, in general, the deeper-seated coal has been subjected

[11] David White, "Quelques relations entre les charbons de différentes espèces et la composition des dépôts sédimentaires originels," *Extrait du Livre Jubilaire publié du l'occasion du Cinquantenaire de la fondation de la Société Géologique de Belgique* (1926), p. 377.

[12] Accordingly, if the rate of downward increase in carbonization of the coals is determined here, it may be used in roughly compensating the fixed carbon at other points where it may be necessary to utilize the analysis of a coal above or below that on which the region is contoured.

[13] H. D. Rogers, "An Inquiry into the Origin of the Appalachian Coal Strata," *Assoc. Amer. Geol. and Nat., Trans. for 1843*, pp. 433–73; *Proc. Phil. Soc. Glasgow*, Vol. 4 (1850), pp. 355–59; *Geology of Pennsylvania*, Vol. 2 (1858), p. 995.

presumably to greater horizontal stress and certainly to greater load pressure, I am inclined to regard the successive downward advances from coal to coal as due to an appreciable extent to the temperature increment, the effectiveness of which is given exponential value by geologic time. If this is true of coals, it probably is true also of oils.

RELATIONS OF INTRUSIVES TO EFFECTS OF REGIONAL METAMORPHISM

Detailed distinctions between heat alteration, essentially distillation under loading, of the organic sediments, as by batholiths or laccolithic intrusions, and normal regional metamorphism cannot yet be drawn. The subject deserves searching and critical investigation both in the field and in the laboratory. Doubtless there are many cases where heat from such sources, superposed on the normal value of temperature, affected the regional metamorphism over restricted areas, besides accomplishing local metamorphism of the contact type.

In general, regional progressive metamorphism of the organic matter appears to go forward in regions without trace of laccoliths and with little regard to minor local intrusives.

A nest of peridotite dikes, apparently of late Cretaceous age, is found in Elliot County, Kentucky, not far within the western border of the coal field and in that part of the Appalachian Trough where carbonization is lowest. Other occurrences of peridotite of the same system and probably of the same age are present a few miles above the mouth of the Monongahela River, at Edenborn, and at Dixonville, Indiana County, in Pennsylvania.[14] The relatively low regional carbonization of these parts of the basin does not seem to be in the least affected by the intrusives or their magmatic sources, as such sources may be conjecturally located beneath an arc passing from the vicinity of Syracuse and Ithaca, New York, to Murfreesboro, Arkansas.

Miss Stadnichenko points out that:

> The areas of known post-Cambrian igneous rocks (chiefly intrusive in the Triassic red shale) nearest to the Lower Kittanning coal are in Adams County, within 90 miles of the higher rank (low-volatile) coals. The coals of the Broad Top field (Lower Kittanning), lying some 30 to 35 miles nearer to the intrusives, are, however, less carbonized than those of the Johnstown-Windber area.

On the other hand, that part of the anthracite region of Pennsylvania that lies nearest abreast of the Triassic igneous intrusives is character-

[14] A. P. Honess and C. K. Graeber, "A New Occurrence of an Igneous Dike in Southwestern Pennsylvania," *Amer. Jour. Sci.*, Vol. 7 (1924), p. 315.

ized by relatively high percentages of volatile matter, the coal being apparently in close approach to the semianthracite rank.

Peridotite dikes of the system already mentioned cut coal beds north and west of the area of highest carbonization in southeastern Illinois, but the effects, obviously local, can not be recognized more than 8 feet from the wall of frozen magma. A stock near the southern border of the coal field seems to have no connection with the direction or progress in carbonization.

Exceptional opportunities to compare the effects of contact metamorphism with pressure-metamorphism are to be found in the Trinidad and Crested Butte coal fields of Colorado and the Cascade fields of Washington and Vancouver. At the southeast corner of the Trinidad coal field, the area of highest carbonization of the field, coals of lower fixed carbon lie between the Starkville coal, highest in fixed carbon, and the volcanic sill that caps the group. From this locality the carbonization appears to decline slowly, both toward the mountains on the west and to the northeast—that is, toward the Spanish Peaks, from which radiating dikes traverse the coal fields through many miles, with sunburst effect in all directions. Before the coal has passed the remarkable group of volcanic plugs, the carbonization has gradually declined below the beehive coking point and on to a still lower rank beyond Walsenburg. Though the coal beds are at many points invaded by thin sills causing contact metamorphism through but a few feet, this regional increase of carbonization proceeds apparently without reference to the presence or direction of the intrusives.

The Crested Butte field, in which the coal ranges from a hard vitrainous anthracite, the carbonization of which is generally regarded as due to a laccolith, through a semibituminous and coking rank, on to a low-volatile gassy coal near Newcastle, on the northeast, and through a coking to a medium-volatile coal on the southeast, invites studious investigation in which well-located and adequate coal analyses should be utilized. In such examinations the value of a large intrusive mass as a compressive factor should also not be overlooked.

METAMORPHISM AND OIL GENERATION

That the organic sediments serving as the mother rocks of oil are buried while they are in process of partial biochemical decomposition and are further altered in the course of time through the same physical agencies that cause the metamorphism of the mother substances of coal and other sedimentary deposits, including those of inorganic origin and of simpler chemical structure, is a geologic fact now generally accepted, though opinions differ widely as to details, both

of the method and of the results. Nearly a century ago, H. D. Rogers called attention to the fact that

the coal strata, especially the beds of coal themselves, are, of all known sedimentary deposits, those which disclose best the various degrees or shades of metamorphic action; the coal, from its superior susceptibility to permanent change of texture and chemical decomposition, with extrication of its more volatile ingredients under a moderate heat, being, indeed, a sort of *very sensitive natural register thermometer*, recording the different grades of temperature to which the strata have been exposed.[15]

Rogers refused to recognize pressure as a factor in metamorphism.

As before mentioned, the organisms of the low orders regarded as furnishing the oils are more generally planktonic and fatty than those that form coal, yielding much larger portions of hydrogen-rich condensible distillates at all but the last stages of distillation, the products being chemically and physically closer to crude petroleums. The mother organic débris of coal, on the other hand, though there is nearly always some intergradation, is contrastingly high in oxygen;[16] through biochemical decomposition it becomes humic instead of fatty or "bituminous," with less volatile matter, and at all stages its distillates are much smaller and as a whole far less like the yields from the mother rocks of oil. A rich cannel, composed largely of spore and pollen exines, which are waxy and resinic and so are low in oxygen and high in hydrogen, may with little aid of included fatty colonial algæ, yield as much as 45 gallons of oil per ton, if not of too high rank. A high-grade oil shale, one-half inorganic, containing vestiges of algæ and some plankton, with some spore exines, may, at the rank of a high-volatile bituminous coal, yield 60 gallons of condensible distillate per ton; or if the organic matter, of the same types, is as low in ash as the rich cannel, the yield may be as much as 80 gallons—that is, considerably in excess of the cannel distillates and containing a far richer mixture. Generally the fatty colonial alga deposits furnish most oil distillates, the amounts being greater where the shales (not too far altered) are purer, and in particular where, other things being equal, the "gelatinous" algæ are best preserved. A Scotch torbanite in which few of the alga (*Pila*) colonies are well preserved, though ash is moderate, may give 120 gallons per ton, but if the mother rock is very pure, resembling a pale golden jelly in which innumerable well-pre-

[15] H. D. Rogers, *Amer. Assoc. Geol. and Nat., Trans.* (1843), pp. 433–73; Quoted in "On the Distribution and Probable Origin of the Petroleum, or Rock Oil of Western Pennsylvania, New York, and Ohio," *Proc. Phil. Soc. Glasgow*, Vol. 4 (May 2, 1860), pp. 355, 359.

[16] David White, "The Carbonaceous Sediments," in W. H. Twenhofel and others, *Treatise on Sedimentation*, 2d ed. (1932), pp. 351–430.

served *Pila* colonies lie suspended as if hardly in contact, the yield may exceed 170 gallons per ton of rock. Supplies of this high-grade alga coal were brought to Boston and New Bedford to feed the oil-shale industry in the period just preceding the drilling of the Drake well in 1859.

As the result of laboratory experiments, Hackford[17] concludes that oils and bitumens may be produced from algæ or their decomposition products by slow acid hydrolysis at low temperatures.

Most "carbonaceous" shales, "bituminous" shales, "black shales," and "dirty mud" shales, or carbonaceous and bituminous limestones and sandstones, contain relatively small proportions of organic matter. This is not only shown by many analyses of marine carbonaceous (black) shales; it is indicated also by the many hundreds of bottom samples, including those from many areas regarded as most favorably located in the world, tested by Trask[18] and Hammar.[19] Of these, relatively few samples contained as much as 7 or 8 per cent of organic matter. In fact, Trask regards as effective mother rock some oil-field sediments containing not over 1.5 per cent of organic matter.

The small amount of organic matter reported by Trask in the recent sediments regarded as possible mother rocks of oil is the more surprising in view of the fact that nearly all the bottom samples tested were taken at or close to the surface of the fallen matter, so that the organic débris was still in process of decay. Consequently, as is illustrated in Trask's tables, the percentage of organic matter, including the nitrogen, was distinctly greater than it would be at a later date or at a greater depth, when and where the process of biochemical decomposition would presumably have been suspended and the sediment brought to its final or completed state in the recent deposit.

Between the rich "oil shale" and the common relatively lean black or "bituminous" shale the transition is complete. In the latter a greater variety of organisms may take part than in a boghead, though a few may predominate. The same kinds may be present, but not in such remarkable numbers or state of preservation as in the smothering organic showers, "turbios" in effect, which appear to have

[17] J. E. Hackford, "The Chemistry of the Conversion of Algæ into Bitumen and Petroleum, and of the Fucosite-Petroleum Cycle," *Inst. Petrol. Tech. Jour.*, Vol. 18, No. 100 (1932), p. 74.

[18] P. D. Trask, 15th Ann. Meeting Amer. Petr. Inst., Dallas, Texas, November 15, 1934, program.

[19] P. D. Trask, H. E. Hammar, and C. C. Williams, *Origin and Environment of Source Sediments of Petroleum*, Gulf Publishing Company, Houston, Texas (1932), p. 185.

produced the typical torbanite or which yield the rather astounding deposits of diatoms, protozoans, or copepods of the present day. In the stagnant or relatively inert waters in which marine black shale is deposited, the products of the partial decomposition of the organic matter are less concentrated, and the supply of organisms, largely plankton, is in general less voluminous, thus favoring more advanced decomposition.

Most regrettably, very little attention has been given to the paleontology or the micro-chemistry of the micro-débris giving value either to the rich oil shales or to the leaner types of mother deposits from which the Appalachian and Rocky Mountain fields, for example, are presumed to have been supplied.

In general it probably may be safely assumed that the temperatures prevailing in the zones of oil generation in the different fields at the time of increased orogeny and oil genesis were not much higher than those now found at depth in oil fields that evidently have been but recently subjected to orogenic stress and perhaps are undergoing pressure deformation at the present moment. If, therefore, we can obtain sufficient data on geothermal gradients in the most active regions free from volcanic, hot-spring, or other relatively direct magmatic influences, it may be possible roughly to calculate the maximum temperature prevailing in the mother rock or even in the deepest sediments above the fully metamorphosed basement complex at the time of their greatest orogeny.[20] Indubitably, the Quaternary is a period of major and widespread orogeny and isostatic adjustment, led up to with growing vigor in the late Tertiary. We are still in the Quaternary.

Meanwhile, viewing the coastal region of southern California as one in which orogeny is now certainly in active progress—possibly as active as in most regions at the time of intense orogenic stress—we may tentatively use the temperature-gradient data available in that region for rude calculations as to temperatures in the oil fields at times of their most active movements. The Tertiary of this part of California may really be as active, under as great pressure, and as hot at the present moment as it ever was, so slow are geologic processes and so long is geologic time, though further deformation and higher temperatures are probably to come.

As offering a steep gradient in an area regarded as free from immediate magmatic heat, Huntington Beach may be chosen. Its steep-

[20] Such geothermic data are at present painfully meager, but it is to be hoped that no chance to obtain such information will be wasted. Opportunities may be offered in the West Coast states, in Alaska, or in the Andean region.

est gradient, approximately 38 feet to the degree Fahrenheit, is reliably determined.[21] Other gradients in the same belt, which may be mentioned as showing that Huntington Beach is not unique, are those of Long Beach, approximately 45 feet to the degree, and Seal Beach, which in temperature is nearer to Huntington Beach.

Accepting Huntington Beach as representing the gradient of an oil dome at the time of or soon after its last orogenic advance, with consequent metamorphism and oil generation, we find that the temperature in the mother rock should be about 195° F., which may well fall within a generative zone at a depth of 5,000 feet; or 318° F. for a depth of 10,000 feet. The latter depth should find light oil in the beds involved. There is no reason to conclude that it has ever been hotter at this point.

In the Belridge field, which appears to be a little removed from the belts of highest orogeny in California, it seems probable that the temperature at the bottom of the Berry No. 1 well (11,377 feet) is near or a little above the boiling point. Mother rocks may lie at great depth below the bottom of the Berry well, for the "unaltered" sedimentary section is extremely thick. Questions naturally arise, then, not only as to whether the bottom of this well is at the present moment in an environment of oil generation and enrichment, but whether, with presumable downward increase in heat and pressure, the bottom of the "unaltered" Upper Cretaceous may lie near the extinction zone.

It is interesting to recall in this connection that pre-Cambrian crystalline rocks lie less than 6,000 feet below the restored land surface of the oil fields of northwestern Ohio, Indiana, central Kentucky, and Illinois, in none of which, except, perhaps, a small area near the mouth of the Saline River, in southeastern Illinois, does the carbonization appear to reach the extinction zone. The temperature could not have been high in the mother rocks, though the metamorphic basement may have transmitted much heat, to be blanketed and conserved by the less conductive overlying sediments, with consequent great steepening of the gradient therein through a considerable period.

The figures cited above may have little present value except as provoking thought and investigation.

In discussing temperature as a factor in the regional metamorphism of organic substances, we must bear in mind the not yet fully determined but certainly great extent to which time is substituted for temperature, especially when pressure is high and plays, perhaps,

[21] C. E. Van Orstrand, "Temperature Gradients," in *Problems of Petroleum Geology* (1934), pp. 989–1021.

a leading rôle. Maier and Zimmerly,[22] using Green River shale in their laboratory, found that the temperature required to transform the organic matter into bitumen was reduced from 365° C. to about 275° C. when the time was greatly extended. Calculations based on their experiments were to the effect that at 100° C. 1 per cent of the organic matter would be converted to bitumen in 84,000 years, or at 60° C. (140° F.) in 67,000,000 years.[23] McCoy,[24] though reluctant to allow so much time, regards 140° F., the equivalent of 60° C., as a higher temperature than is required for oil generation.

Pressures were not at all times known in the Maier and Zimmerly tests, and little allowance was made for them; but they were relatively low, as compared with oil-field pressures, even at shallow depths. Unpublished experiments on bituminous shales, with accurate determinations of temperature and more closely controlled as well as much higher pressures, by Miss Stadnichenko, indicate notable reductions in temperature where pressure is high.

As to the importance of the heat of chemical reaction of the organic matters in the mother rocks, attention may be again called to Trask's world-wide survey of recent sediments, presumably deposited under favorable conditions. Organic matter totaling not more than 1.5 per cent, or even as low as 0.9 per cent, does not seem sufficient to generate any considerable temperature in the strata or even to heat the core of an oil-bearing anticline. Greater heat might possibly be found where oil sealed in storage has undergone metamorphism.

In many regions of the earth in which thick Algonkian series are present, great deposits of black shale and carbonaceous limestone were laid down, the original value of which as mother rock can hardly be questioned, though they are now altered beyond the extinction zone of commercial oil. Doubtless some of these deposits furnished oil in an earlier period. Some of the hydrocarbons included in granites may have originated in these pre-Cambrian organic deposits.

The carbonization of what may be styled the "spore aggregate," which is mainly responsible for the fattiness of coals of the cannel type, appears to lag perceptibly behind that of the ordinary banded coal, as I have elsewhere stressed;[25] but, as shown also in the cannel

[22] C. G. Maier and S. R. Zimmerly, "The Chemical Dynamics of the Transformation of the Organic Matter to Bitumen in Oil Shale," *Univ. Utah Bull.*, Vol. 14, No. 7 (1924), pp. 62–81.

[23] P. D. Trask, "Time Versus Temperature in Petroleum Generation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 1 (January, 1931), pp. 83–84.

[24] Alex. W. McCoy, in *Problems of Petroleum Geology* (1934), p. 269.

[25] David White, "Quelques relations entre les charbons de différentes espèces et la

and alga-torbanite groups, it seems to overtake the common banded coal in loss of volatile matter before it passes through the semibituminous ranks. All organic matters appear to reach the anthracitic and graphitic stages simultaneously.

While again reminding my readers that the physical agencies, principally pressure, temperature, and time, by which—together with minor factors such as depth of load, thermal conductivity, colloidal states, catalysts, heat of chemical reaction, chemical association, ionization, and enzymes—the metamorphism of the organic mother rocks of coal and of oil is accomplished, act simultaneously on the inorganic as well as the organic matter, though not with so conspicuous effects in these early stages of metamorphism, I would also remind them that biochemistry or bacterial activity may similarly alter the chemistry, color, and crystallology of the recent inorganic sediments.

By experimentation, reported in this *Bulletin* (1931, p. 611), B. T. Brooks found that a considerable number of sediments not previously expected to exert catalytic influence may cause polymerization of unsaturated hydrocarbons.

Under the same aggregate of major and minor metamorphic factors, peats are transformed to anthracites and graphitic coals; mother rocks of oil to bituminous shales; the residues of metamorphosed oils to graphites; carbonaceous and bituminous shales to graphitic slates and schists; and carbonaceous sands to graphitic sandstones, graphitic quartzites, and graphitic gneisses. These products embrace the solid organic residues not only of the primary organic sediments, but also of the primary and later oils.

Very recently a friendly critic writes:

> The assumption that oil is generated only by dynamochemical alteration of organic source materials (implied in a number of articles cited in this paper) is contradicted by what is now known of the occurrence of oil in relatively young sedimentary formations.[26]

The basis for argument as to how the assumption is "contradicted" by the facts now "known" seems to lie in the apparent belief of my critic that the "relatively young sedimentary formations"—meaning, I presume, formations in which oils have nevertheless been *generated*—have not experienced any "dynamochemical" changes of the mother rock or other sediments.

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composition des dépôts sédimentaires originels," *Extrait du Livre Jubilaire publié de l'occasion du Cinquantenaire de la fondation de la Société Géologique de Belgique* (1926), p. 377.

[26] W. Taylor Thom, in *Problems of Petroleum Geology*, p. 78.

Too frequently geologists overlook the fact that the metamorphism of chemically organic rocks begins with the changes in the chemical and physical states of the new sedimentary deposits—chemical changes attending biochemical action in the deposited débris and physical changes occurring in the long process of "devolatilization"; physical changes beginning with progressive compression, lithification, dehydration, and cleavage, together with such crystallization and recrystallization as may be incident to the chemical and physical changes.

If the entire scale of rock metamorphism be graduated in 100 units, the metamorphism of those rocks ordinarily termed "metamorphic" by hard-rock geologists may be conceived as falling between 60 and 100 units on the scale, while the changes observed in the mother rocks of coal and of oil range between 5 and 65 on the scale, in which ordinary bituminous coals may fall between 35 and 50. These numbers have only suggestive value. Crystallization, long known both in oils and in coals, with change of optical properties marking changes of rank, has also been observed in oil shales. The crystallography of both coals and mother substances of oil invites research.

As I view it, metamorphism is already in progress when the mother sediments, under an increasing load of rock-forming material, are in process of compression and dehydration, with elimination of gases and other organic decomposition products involving chemical reactions and the formation of sulphides, some of which are crystalline, and with other less conspicuous changes, such as oxidation and deoxidation. Metamorphism may be regarded as overlapping the stage of biochemical or bacterial action which attends and immediately follows the deposition of the organic débris, as I long ago pointed out. Whether oil is generated at so early a stage is another question, satisfactory proof of which appears to me to be still in default.

It is generally believed that the action of the anaerobic bacteria that effect the decomposition of the more resistant organic débris is suspended within very shallow depths, beyond which no more oxygen can be made available by them for their use in the recent organic deposits. So far as I have been able to recall, live bacteria have in no case been proved to function at a depth greater than 18 feet in any peat deposit, though active bacteria are reported as present in oil-field sands and brines as old as the Ordovician.[27] Fossil bacteria have been described in silicified woods, in silicified coprolites from the

[27] E. S. Bastin, "The Problem of the Natural Reduction of the Sulphates," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 1270–99.

Permian of France, and in humified bark of Mississippian age. Claims as to the discovery of live bacteria capable of resuming their normal function in Paleozoic coals in the Ruhr Basin[28] and in Pennsylvania[29] demand the most exacting corroboration, especially in view of the contradictory testimony resulting from a single check-up of the American discovery.[30] Yet, if it is true that bacteria buried 700 millions of years ago, at the time of deposition of the rock, or bred from others so buried, are now brought alive to the surface of the earth after burial 20,000 feet deep in pre-Cambrian Bass limestone found near the bottom of the Grand Canyon, as stated by the same authority as for the anthracite, we should be able to give credence to the survival of life through the vicissitudes of orogenic compression, incredible concentration of humic acids, dehydration, chemical reactions, heat, elimination of hydrogen, progressive loss of oxygen beyond the point tolerated by any known living bacteria, and possible crystallization of a remaining mass of great carbon molecules, all within a period of 225,000,000 years.

Some students of coal in Germany have sought to explain differences in the ranks of coal from lignite to anthracite as due to the work of bacteria acting in different kinds of organic matter, or, perhaps, the work of different kinds of bacteria operating on similar or identical organic matters.

The followers of the bacterial hypothesis—of whom there are many in Europe—do not explain why the carbonization of the organic mother substances increases downward, nor why it runs progressively, horizontally, and *parallel with the regional metamorphism of the inorganic rocks* and in the same lateral direction; nor why it progresses, *pari passu*, with the progressive dehydration; nor why in particular, without change in the flora or the constituent structure of the coal, the increasing metamorphism may be followed from stage to stage in a single coal bed, as was emphasized by Rogers in 1843 and as has been recently shown in detail by Miss Stadnichenko.

That petroleum is generated *only* under dynamic influences can not be said to be proved beyond question; but in view of the evidence available in many parts of the world, as well as demonstrable in the laboratory, that oils may be produced directly from the mother substance within several temperature zones by distillation, or from

[28] Franz Fischer, "Biology and Coal," *3d Internat. Conf. Bitum. Coal*, Pittsburgh (1931), pp. 809–20.

[29] C. B. Lipman, "Living Micro-organisms in Ancient Rocks," *Jour. Bact.*, Vol. 22 (1931), pp. 183–98.

[30] Michael Farrel and H. G. Turner, *Fuel*, Vol. 11, No. 6 (1932), pp. 229–32.

other oils by distillation, by cracking, or by hydrogenation, the assumption appears legitimate, especially if the numerous failures to find indubitably indigenous petroleum anywhere in absolutely unaltered sediments are taken into account. Trask, who has examined over 2,000 samples of sediments from many environments, including those now regarded by most geologists as favorable for the deposition of mother rocks, states[31] that "in no case were any liquid hydrocarbons present." L. A. Thayer[32] and K. Hashimoto, working on the remarkable diatom deposits on Copalis Beach, Washington, seem to have met no better success in this respect.

OROGENIC ADVANCES MARKED BY METAMORPHISM OF MOTHER ROCKS AND OILS

That the regional metamorphism of the organic matters of the sedimentary deposits presents the incipient phases of true metamorphism must at all times be borne in mind. Further, this metamorphism, along with that of other rock material, being caused by the same dynamic factors—primarily pressure, temperature, and time—takes place at the same time as the metamorphism of the other rocks—namely, at times of increase of orogenic activity to greater intensities than before, with its further increases of pressure and temperature, which are in some cases perhaps wholly consequent to the others. It conforms to the law of progressive advance of the points of thermal decomposition of the organic matter.

Following the stages of progress of the metamorphism of the organic matters as marking advances in the general metamorphism of the region, we reach the "*extinction zone*" within which the volatile products of insensibly slow and incredibly low-temperature distillation, cracking, and enrichment, becoming lighter and lighter, are no longer condensable at normal atmospheric temperatures and pressures. Beyond this line the unassimilated and unabsorbed gases, together with those newly generated, as carbonization of the residues goes onward with concentration of carbon in heavier molecules in the rock, may escape or find storage in gas fields, as we now meet them in zones of still more advanced metamorphism, beyond the extinction zone of the oil field.

In considering the migration as well as the origin of the volatile hydrocarbons—when passing, for example, as they obviously did, whether vertically or horizontally, out of a supposedly "impervious"

[31] P. D. Trask and C. C. Wu, "Does Petroleum Form in Sediments at Time of Deposition?", *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 1451–63.

[32] L. A. Thayer, *Amer. Petrol. Inst. Research Program*, Pt. 3 (June, 1932) pp. 12–13.

clay sediment in which the mother substance may have been laid down—we must not forget that the crust of the earth is perpetually (though variably) and everywhere subject to movements, in response to most complicated stresses, which are always varying in intensity, in direction, and in magnitude, from region to region, from point to point, and from time to time. Imperviousness and rigidity should more often be thought of as relative. Not only migration but escape of volatile hydrocarbons may in the course of time of geologic length have been aided by possible minor factors, such as microseisms, tidal drag, changes in terrestrial magnetism and ionization, and even solar electrical variation, as well as by earthquakes and other "visible" strains. Nevertheless, the conclusion that the great migrations as well as the great steps in the evolution of oils and gases were accomplished mainly in periods of orogeny appears fully justified.

THE EXTINCTION ZONE

The extinction zone may be defined as the stage or zone in the metamorphism ("carbonization") of the organic sediments and their liquid products at which the oils, generally becoming lighter and lighter, are no longer stable and liquid at atmospheric temperature and pressure.

My critic who states that the "dead line," or the "carbon-ratio limit," is hypothetically drawn is wrong. It is purely observational in general location, as well as in detailed demarcation from field to field and province to province. Its approximate definition is based on trial and error. It lacks a vast volume of needed field data on comparative coal carbonization, drawn from all possible regions and oil- and coal-bearing geosynclines. In too many cases, I have used defective or nonstandardized analyses. It is probable that the hydrocarbons generated from the varying types of mother rocks characteristic of the different fields do not actually all roll out in the final noncondensable hydrocarbon zone at so very nearly the same point in the progressive carbonization as I have assumed. Nevertheless, I have yet to learn of an authoritative occurrence of oil in commercial amounts within the extinction zone as originally defined by me—namely, 65 to 70 per cent of fixed carbon.[33] In fact, it is probable that little commercial oil will, in general, have been found where the reliably determined carbonization exceeds 62. In some regions the limit may be as low as 60. Areas illustrative of such a lower limit seem to

[33] All statements of fixed carbon given in my papers are on the ash-, moisture-, and sulphur-free basis. The determination of fixed carbon in low-rank coals (subbituminous and lower) by the ordinary proximate analysis is unreliable.

be present in the Rocky Mountain region, though it is possible that the impression is due to misleading coal analyses. It is, however, my tentative idea that the limit is slightly higher in those regions, such as the northern part of the Appalachian Trough, which have long been relatively quiet, where the temperature gradient is very low, and where the hydrocarbon compounds have had longest time to re-form and stabilize at lowest temperatures and depths (loads) in the sands.

Further critical comparisons, which are obviously demanded, will, I am sure, lead to a sharper and narrower delineation, of far greater economic importance, of the extinction zone, which, further, may be found to vary slightly with the type of the oil—that is, the type of mother rock as deposited—as well as with the conditions and varying influences of the causal dynamic factors.

ONE OR SEVERAL CYCLES OF OIL GENERATION FROM THE MOTHER ROCK?

Recalling the well known Cunningham-Craig theory that the generation of oil from the organic matter takes place at the time of deposition—during the period of biochemical deposition, and possibly in consequence of biochemical processes—and the views of Barton and Thom, already mentioned, we encounter the important questions not only as to whether oil is formed at or soon after deposition of the sediment, possibly in advance of and independent of any dynamic influence, but also as to whether all the oil is formed during a single interval.

For reasons stated on previous pages, I am unable to accept the biochemical theory of origin. The discoveries of oil in recent sediments, as reported by Jones[34] for the Lake Lahontan deposits, or as described by other authors for areas near the Red Sea and in other regions, appear inadequate as proof of what should be a common and widespread phenomenon if the theory is sound. Assuredly the discoveries cited deserve searching examination, in view of the frequency of leakage or surface seepages of oil from deeper-seated reservoirs or centers of generation.

To my mind it seems neither logical nor probable that all the volatile matter generated underground and condensable in its natural environment by the natural processes will have been produced at so obviously an early stage, at which it is overwhelmingly and conclusively shown that a great part, if not by far the greatest part, of the volatile matter condensable as oils when distilled still remains

[34] J. Claude Jones, "Suggestive Evidence on the Origin of Petroleum and Oil Shale," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 7 (1923), p. 67.

in the mother rock. Laboratory experiments with oil shales, bituminous shales, and coals by Wheeler, Miss Stadnichenko, and others show successive advances of the points of thermal decomposition of the organic débris following advances in carbonization. This has been abundantly proved both by consecutive tests on the same material at higher temperatures and by tests of mother rocks at different stages of natural underground carbonization. Distillates are condensable until a point is reached where only noncondensable gases are evolved, a point presumably corresponding to the extinction zone. The zones of decomposition, accurately measured by Miss Stadnichenko, who distilled the samples in an inert atmosphere, are distributed through a wide range of temperature, generally in excess of 300°C.[35]

As is well known, the oil distillates obtained from oil shales and other carbonaceous shales at the different temperature zones yielding condensable volatile matter differ in chemical and physical characters. The first products, beginning at 100° to 120°C., in young deposits comprise methane and ethane. At higher temperatures heavy unsaturated hydrocarbons and tarry products follow. These are succeeded at still higher temperatures by lighter oils of higher rank, and these in turn by gases, including hydrogen and methane, at about 550° C., the temperature varying somewhat with the character of the rock. Both the characters of the distillates and, especially, the temperatures of recovery must vary if the pressure and time factors are introduced, and the presumption that the products will approach the natural oils more and more closely as the conditions existing in nature are more closely duplicated is beyond doubt justified.

The distillates in their sequence are roughly in accord with the natural oils which, as found in the younger and little-metamorphosed formations, are heavier (naphthenic and asphaltic), more varied in composition, and, in general, of lower grade than those found in the zones of greater carbonization, in which the oils advance up to the extinction (gas) zone. The oils in the successively deeper and older underlying formations are in general higher in rank than those in the shallower formations, notwithstanding the many anomalies recorded by Bartram[36] from the Rocky Mountain states.

In this connection it may be noted that Trask,[37] who has made

[35] Taisia Stadnichenko and David White, "Microthermal Observations of Some Oil Shales and Other Carbonaceous Rocks," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), pp. 860–76; "Microthermal Studies of Some 'Mother Rocks' of Petroleum from Alaska," *ibid.*, Vol. 13 (1929), pp. 823–48.

[36] John G. Bartram, "Oil Gravities in the Rocky Mountain States," *Problems of Petroleum Geology* (1934), pp. 157–76.

[37] P. D. Trask, "Results of the American Petroleum Institute Research Project on

many hundreds of determinations of nitrogen in supposed mother rocks for use as indices of the total organic matter, finds the decline in nitrogen most marked in passing from the recent sediment to the Pliocene (California) mother rock, whence he infers that oil generation may well have been most active in that interval; but the further decline of nitrogen in the mother rocks of different ages he regards as in harmony with further oil formation in later periods. However, as nearly all the recent sediments tested by Trask and Hammar were taken from the surface of the sea bottom, very few having come from depths as great as 3 feet, it is evident that his organic matter still included fresh material with more of the original nitrogen compounds, as well as other animal and plant débris, in which decay was still in progress and biochemical action not yet suspended. Therefore, the nitrogen in his samples of "recent" sediments is most probably considerably higher than in the recent mature sediments, more deeply covered, in which bacterial action was suspended or at least was much farther advanced. This obvious situation finds confirmation in Trask's observation of the downward decrease of organic matter (calculated from the nitrogen index) in his recent bottom deposits.

The dehydration of the organic sediment, which is much discussed by petroleum geologists in connection with the origin and migration of oil, begins at once with loading and continues until the organic residues are anthracized. At the surface of the water-covered deposit the organic peat or mud contains 85 per cent or more—often over 90 per cent—of water. By the time the deposit reaches the stage of a consolidated brown lignite, the squeezing process has reduced the water to 25 per cent, roughly, of the deposit. The subbituminous coal or "black lignite" still contains moisture enough to cause decrepitation on exposure. A content of 10 or 12 per cent of moisture may remain in some of the high-volatile bituminous coals such as those of Illinois and Indiana. About 4 per cent of moisture is left in the air-dried fuel when the carbonization of the common coal reaches 62 per cent and the extinction zone, and still less when, at about 85 per cent of fixed carbon (pure coal basis), cementation, with losses of hydrogen and B.t.u. value, sets in as the coal passes, with further losses of volatile matter, into the anthracite group.

Meanwhile, as the water, gas, and oil are being expelled from the mother matrix, always struggling to move in the direction of least resistance—in general from the more compressible into the less compressible rock—the mother rock—for example, the bituminous shale

Origin and Environment of Source Sediments," *Proc. Amer. Pet. Inst.*, 14 M (IV), pp. 19–31 (1933). (*Prod. Bull. 211.*)

—is reduced in volume by pressure. Studying the compression of shale, Athy[38] concludes that the reduction is 20 per cent at a depth of 1,000 feet, 40 per cent at 3,000 feet, and 47 per cent at 6,000 feet.

As we know that the mother rocks in many areas have gone through several cycles of generation of volatile matter before reaching their present stage, and that oils are produced at several of these cycles when the rock is distilled, it is difficult to conclude that they have yielded naturally condensable volatile matter only at the outset. In view of the existing field and laboratory data, the assumption that oil is generated in more than one period needs no defense. On the other hand, the burden of proof seems to lie with those who postulate origin only in the first instance.

However, notwithstanding the probability, as I see it, that successive generations of oil are produced from the mother rock as metamorphism advances, it seems by no means improbable that reorganization with hydrogenation of the liquid hydrocarbons in confinement under pressure, with the aid of temperature and much time, may take place at a much earlier stage of metamorphism than I have assumed, though it still appears to me that the phenomena of cracking and enrichment may be more characteristic of the middle and later stages of oil generation from the mother substance and that both the older oils and oil newly produced from the mother rock are subject to hydrogenation, or methylation, as proposed by Wilde and Pratt,[39] which may be especially characteristic of the last stages, marked in shale-distillation tests by increasing hydrogen and methane.

Furthermore, in view of the very great contrasts in the relative time and temperature factors and the differences in pressures in the natural earth environment as compared with those factors as applied in the oil refinery or laboratory, we are, I believe, justified in assuming that enrichment proceeded even at the time of cracking, as suggested by Rich and Pratt,[40] underground, with methane and hydro-

[38] L. F. Athy, "Compaction and Oil Migration," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 25–36.

[39] Wallace E. Pratt, "Hydrogenation and the Origin of Oil," *Problems of Petroleum Geology* (1934), pp. 240, 243.

[40] W. E. Pratt says (*op. cit.*, p. 243), "The initial cracking of the source material to form gas and heavy oil probably goes forward at a relatively rapid rate. Hydrogenation or methylation would proceed more slowly, and with its progress, as John L. Rich has suggested, a slower cracking would also be expected to continue. This secondary cracking would split up the molecules of heavy oil into smaller, lighter molecules, with a continuously lighter oil as a result, while hydrogenation gradually saturated the molecules with hydrogen. Thus hydrogenation and cracking would go forward side by side in petroleum reservoirs for long periods, during which the typical oil slowly became lighter in gravity and more fully saturated with hydrogen."

gen at hand, the products being more fully or in part quite saturated at earlier stages than might be inferred from refinery results.

With reference to basic differences in the oils, it may be recalled that in oil rocks ranging up to the rank of a high-volatile bituminous coal Miss Stadnichenko[41] found the different types of débris that are readily visible under the microscope to possess chemical distinctions proved by their different points of thermal decomposition.

VARYING CHARACTERS OF COALS AND OILS AFFECTING DEFINITION OF EXTINCTION ZONE

It has been urged by some geologists that the "dead line" or extinction zone can not be closely defined for all fields, on account of probable differences in the extinction zones of different types of oil or on account of differences in the coals used in drawing the boundaries. Such a conclusion as to the oils appears reasonable, within narrow limits.

Much discussion has been offered by many writers, mainly chemists, of the relations of particular ingredient components—such as spore exines, resin grains, fusain, vitrainized structures, or cuticular layers, which take part in characterizing the types of coal—to the chemical composition of the coal itself and its uses. For the most part, however, these studies have been of little profit, on account of their failure to recognize the evolution of the coal and the chemical changes that take place in the course of the metamorphism of its type components from rank to rank.

It has long been recognized that fusain is associated with "dryness" and disinclination to coke in bituminous coals, and that high-volatile products rich in hydrogen, low in oxygen, and of great illuminative power were to be obtained by the distillation of the sporiferous low-rank bituminous coals. Beyond these facts, however, and the further important capacity of the very fatty cannels and the alga coals, or bogheads, to give very high yields of volatile matter extraordinarily rich in hydrogen, with very little oxygen, and to furnish higher hydrocarbons as oils and waxes, and beyond noting yields of sulphur products, far too little attention has until lately been given, even in the oil-shale distillation laboratories, to the relations between the nature of the mother débris or the chemical composition characterizing the supposed mother rock of oil, on the one hand, and its oil products or gases, on the other. Many geologists have reasoned —probably correctly—as to the sources (edge water, sulphates, lime-

[41] Taisia Stadnichenko, *op. cit.;* also "Some Effects of Metamorphism on Certain Débris in Source Rocks," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 161–64.

stone, et cetera) of the heavy sulphurous oils, or as to the general relations between the source matter and conditions of deposition responsible for oils of special types and features, but there is painful lack of experimental research. It is, accordingly, encouraging to meet discussions like that by Taff[42] of California oils, in which he correlates naphthene oils having a tar base carrying asphalt and generally free from wax or paraffine with a highly diatomaceous source rock, and a naphthene oil containing little or no tar and more or less waxes with *Foraminifera* and other animals in the source rock.

It should not be forgotten that, unless we are basically in error, oil is the product of organic matter of varying chemical compositions laid down under varying conditions, in deposits of consequently varying types; that these deposits also present variant chemically inorganic associations of other rock matters, solid or in solution, which may influence the reaction; that in different provinces the metamorphic factors, primarily temperature (in low degree), pressure, and time, have operated in varying mutual proportions or potency ratios, as well as in varying environments and on varying commodities; and finally—and this is important—that each type of oil-rock deposit, like each deposit of the coal series, must be expected to vary chemically both as to its volatile products and as to its residues, as the process of metamorphism (devolatilization) goes forward.

In view of the complexity of the relations, conditions, and processes involved in its making, it is not remarkable that petroleum varies from region to region, from formation to formation, and even from locality to locality.

Being no chemist, I have avoided so far as possible chemical discussion of the problems, doubtless assuming impossible relations in some cases and ignoring well established facts in others. As I crudely view the subject, the structures and changes in the products generated in the early stages of the metamorphism of the organic sediments may be imagined as open, diverse, and radiate in direction, whereas those marking the later stages are simpler, restricted, and linear or parallel, becoming more or less identical between all types in the higher ranks, so that all enter the extinction zone largely in the same forms and at the same or very nearly the same time, or stage, in the course of the metamorphism of both the oils and the residues. In and beyond the extinction zone hydrogen and methane are produced for the enrichment of oils in the overlying and less altered formations.

On these premises rest both the zoning, according to their car-

[42] J. A. Taff, "Physical Properties of Petroleum in California," *Problems of Petroleum Geology* (1934), p. 182.

bonization, of the ranks of coals and other organic sediments, and the definition of the extinction zone of the oil fields.

SOURCES OF ERROR IN DEFINING EXTINCTION ZONE

Present causes of error in the use of figures for fixed carbon are the following:

1. Differences in age or in the stratigraphic distance between the coal and the oil zone used in the comparison
2. The use of weathered or partly oxidized coals
3. Lack of international standardization of the empirical method of determining fixed carbon
4. The error, generally not exceeding 0.5 per cent, in the determination of the fixed carbon of the coal
5. Very large proportions of fusain (mineral charcoal) in the coal, causing high fixed carbon
6. Fatty matter such as spore exines or fatty algae, which may cause an abnormally low fixed carbon in the coal
7. Use of *contact*-metamorphic figures

In a common banded coal of the 60 per cent fixed carbon rank a very large amount of fusain may cause an excess of 5 or 6 per cent in the fixed carbon, but a moderate excess of fusain should not cause a departure of more than 3 per cent in the fixed carbon of a coal of that rank, while a nearly total lack of fusain may cause a deficiency of similar amount.[43] On the other hand, the fixed carbon of a very pure fatty cannel in the same section with a normal coal of the 55 per cent rank may give but 45 per cent of fixed carbon when analyzed separately, but it would require a very noticeable excess of cannel exines or resins in a banded coal of the 60 per cent rank to cause an apparent deficiency of 5 per cent in the fixed carbon. A thin streak of cannel in a coal bed of the 60 per cent rank should not cause a variation of over 3 per cent, according to its purity. The presence of a large number of fatty algae mingled with the canneloid material may somewhat increase the fixed carbon departure, but the occurrence of such material in noticeable amounts is extremely rare. In short, moderate variations on account of fusain or fatty canneloid material may cause variations of 2 or 3 per cent in fixed carbon, but to cause variations of more than 4 or 5 per cent requires such large amounts of either component as hardly to escape the eye of any geologist or engineer who is in the least familiar with coals.[44] Analyses of low-rank coals

[43] Glistening, fibrous fusain, of a bituminous rank, when isolated and analyzed separately, may yield approximately 85 per cent of fixed carbon.

(subbituminous and lower), which are unreliable, are not likely to be used. None of them approaches the extinction zone.

Departure from what would appear the normal rank of the oil—that is, the grade or type expected, from the locality or from the formation in question, to correspond to the fixed carbon of the coal—is, as time goes on, finding satisfactory explanations as due to such causes as leakage, evaporation, filtration, mixtures by vertical migration, marginal contamination, or buried unconformities. Eventually we should distinguish migrationally commingled ranks, perhaps by means of the methods employed by Barton in the study of the oil deposits of the Gulf Coast salt domes.

As I regard it, the recognition of the evolutionary advance (ranks) of the different type series of oils as products of progressive regional metamorphism is fundamentally consistent with the visible evolution (carbonization) of the types of coal and other organic sediments.

PROBLEMS INVITING COÖPERATION OF PETROLEUM GEOLOGIST, CHEMIST, AND ENGINEER

Cores of coals cut in wells near the extinction zone for standard proximate analysis will be of great value in the closer definition of the extinction zone. If more than one coal is found, data relating to the rate of downward increase in carbonization in the vertical column will be acquired. Depth to carbonization equivalent to the extinction zone may be calculated. In some areas coring of coals may be as important as coring of other strata.

Temperatures should be measured in very deep wells and in new fields, not only to determine the geothermal gradient, but also for calculation of depth to oil of boiling point, depth at which the oil will be unstable and difficult to recover, and probable maximum temperature at the base of the deepest unaltered sediment, or to the basement complex or its equivalent. This is especially important in regions of very recent deformation or where orogenic activity is now in progress, as in parts of California. Temperatures approximating those of oil generation may be deduced; at least the highest temperature that has probably been developed in the oil-producing sediments may be closely estimated.

Oil fields in which metamorphism is clearly due to laccoliths or batholiths should be thoroughly and critically studied.

Micropaleontologic determinations of the chemically organic

[44] The figures given by W. T. Thom in *Problems of Petroleum Geology* (p. 82) approach the percentages for maxima for pure cannels or fusain.

micro-debris in ordinary accepted mother rocks should be made and should be followed so far as possible by microchemical analyses of the different kinds of debris.

Continued studies in field and laboratory should be made of the relations between types of mother rock and the genetic environment and the types of oil, including the different ranks of oil of the same type and source.

Integration, as close as possible, should be made of the relative values of the metamorphic factors effective in *specific fields*, for application to or comparison with other fields, and for study of the relation of these values to differences in the types of the oils.

A method is needed for the reliable determination of the stages of carbonization of carbonaceous shales and other rocks of very low organic content, the results to correspond to or to be calibrated in terms of the fixed carbon of coals. Obviously such a method is greatly to be desired in exploring new regions where coals are not available.

A broadly organized and amply financed institute is needed for research in the problems of petroleum geology and engineering. This need, actually a necessity, will become still more obvious when, probably in the not distant future, the delinquent mind of the American public turns again to oil shale or some source—other, it is hoped, than our most valuable industrial coals—in the search for substitutes for petroleum and its products.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 618-643, 3 FIGS.

VARIATION AND MIGRATION OF CRUDE OIL AT SPINDLETOP, JEFFERSON COUNTY, TEXAS[1]

DONALD C. BARTON[2]
Houston, Texas

ABSTRACT

Four distinctive types of crude oil, one of which is divisible into two subtypes, are present among the fifteen United States Bureau of Mines analyses of Spindletop crude. Types B, C, and D seem indigenous respectively to the Middle Miocene, Lower Miocene, and Oligocene; B is not migrant C or D, and C is not migrant D. Although immigrant into the cap rock, type A is not derived from types B, C, or D. Some of the analyses are from migrant B and C crudes. The change of character of the crude during migration was slight and was mainly in the direction of slight decrease of residuum and of viscosity of the crude as a whole. Stratification according to gravity is shown by type B crude and consists in the main of enrichment of the upper part of the reservoir in the lighter fractions. Increase of the A.P.I. gravity of the crude and of all fractions with increasing depth is shown, and also a tendency toward increase of the lighter half of the distillation fractions.

DESCRIPTION OF FOUR TYPES OF CRUDE OIL

Four different types of crude oil, and two subtypes under type B, seem to be present among the crude oils which are represented by the fifteen United States Bureau of Mines analyses of the Spindletop crude oils.[3] The presence of a fifth type is surmised from the distribution of A.P.I. gravity, but it is not represented among the United States Bureau of Mines analyses.[4]

By inspection of Table I, each of the individual groups into which the analyses have been sorted can be seen to have a common individuality which in certain respects is distinctive from that of the other groups.

[1] Manuscript received, February 8, 1935. Read before the Association at the Wichita meeting, March 23, 1935.

[2] Humble Oil and Refining Company.

[3] Samples numbers 1–14 are from A. J. Kraemer and Peter Grandone, "Analyses of Spindletop, Texas, Crude Oils," *U. S. Bur. Mines Rep. Investigations* (mimeograph), Serial 2808 (May, 1927).
Sample number 15 is an unpublished analysis by the U.S. Bureau of Mines.

[4] Paul Weaver orally has called the writer's attention to a sixth type which has a high wax content, and a high A.P.I. gravity. The analyses of the first four types have a cloud test of less than 5°, and therefore have no wax. The gravity of the fifth surmised type is much lower than that of this sixth type.

The mean individuality of each group is given in Table II, for comparison with that of the other groups and subgroups.

The most important characteristics of a crude oil in studies of the identification of crude from different source beds seem to the writer to be: first, the interval between the gravity of adjacent fractions; second, the gravity of the fractions; possibly third, the viscosity of the crude and of the fractions from 0–200° to 275–300°C. at 40 mm. atmospheric pressure; and lastly, the composition in terms of percentage of each fraction. The gravity of a fraction is closely related to the molecular composition of the fraction and, therefore, the composition of a crude in terms of the respective specific gravities of the constituent fractions is an empirical statement of the present molecular composition. But from his studies, the writer surmises strongly that the gravity of the fractions of naphthene and intermediate base crudes changes under the effects of time, temperature, and pressure. The character of a crude in terms of the gravity of the fractions, therefore, is not an invariant criterion of a particular crude under different conditions. The interval between the gravity of successive fractions would seem to be a more reliably invariant characteristic of a crude under different conditions. Only a reconnaissance survey of the A.P.I. interval between the fractions has been made; but it is evident, for example, that for the interval between the gravity of the fractions 0/200°C. to 200/225°C. 40 mm., only the analyses of Claiborne crudes show an interval of 0 to 0.1 A.P.I.; only the Lower Miocene crude at Spindletop and three Eocene crudes have an interval of 0.2–0.3 A.P.I. The Pliocene crudes, except the Anse La Butte crude, which looks like a migrant crude, have an interval greater than 1.3 A.P.I.; most of the analyses of crude oil from Middle Miocene sands have an interval greater than 1.1 A.P.I.; most of those from Lower Miocene sands have an interval greater than 0.6 A.P.I.; most of those from Oligocene sands have an interval between 0.3 and 1.1 A.P.I. The writer surmises that each crude has a different pattern of intervals between the gravity of the successive fractions. Those intervals, *a priori*, should change less than the gravity of the fractions as the character of the oil changes and, therefore, should tend to be a more reliable criterion to use in following a migrant crude. The primary criteria in the classification of the oils at Spindletop was in the A.P.I. intervals, in the A.P.I. gravity of the fractions, and in the viscosities.

The differences between the respective individualities of the different types of crudes specifically are as follows.

TABLE I

Character of Crude; Samples Grouped by Types

Table Ia. A.P.I. Gravity

	No.	XIV Residuum	XIII 275 300	XII 250 275	XI 225 250	X 200 225	IX 0 200	VIII 250 275	VII 225 250	VI 200 225	V 175 200	IV 150 175	III 125 150	II 100 125	I 75 100	50 75	Crude	Depth in Feet
		(25° C. Distillation Cuts)																
A. Cap-rock Crude	1	109	17.5	19.0	20.2	22.6	24.3	28.2	31.3								19.7	800
B. Middle Miocene																		
Subtype I	2	17.9	18.7	22.0	23.3	24.5	25.4	28.2	31.5	35.4	39.8	45.6	51.1	57.2			29.1	2,715
	7	17.8	19.2	22.0	23.3	24.5	25.6	28.6	33.7	36.2	40.2	46.0	51.8	56.7			28.8	3,005
	5*	17.3	19.2	21.8	23.1	24.2	25.2	28.0	31.1	35.0	39.0	44.3	50.4	56.7			28.4	2,947
	9	17.6	19.2	21.6	23.0	24.2	24.9	27.7	30.8	33.8	38.0	43.4					25.7	3,305
	10	17.5	19.0	21.8	23.0	24.0	25.2	27.9	31.0	34.6	38.6	44.3					26.8	3,305
Subtype II	3	17.0	18.6	21.1	22.5	23.7	24.9	27.9	30.4	34.6	39.0	44.3	50.4	54.9	58.9	66.1	28.2	2,785
	4	16.7	18.6	21.3	22.8	24.0	25.0	27.5	30.8	34.6	39.4	44.7	50.6	55.4	61.0	70.4	28.9	2,947
	6	17.1	19.0	21.3	22.6	24.0	25.2	28.0	31.0	35.0	38.0	44.7	50.1	56.1			26.8	3,005
	8	16.7	18.6	21.1	22.5	23.8	25.2	27.7	30.4	34.2	38.8	44.7	52.3	55.2			27.7	3,024
	12	16.8	19.2	21.3	22.5	23.7	25.0	27.7	30.8	34.4	39.0	44.5					25.6	3,377
C. Lower Miocene																		
	11	19.4	22.8	24.3	25.6	26.6	26.8	29.3	32.3	36.0	40.0	44.9	50.9	57.2	60.8		29.5	3,340
	13	19.2	22.8	24.3	25.7	26.8	27.1	29.5	32.7	36.2	40.0	44.3	50.1	55.4			30.4	3,978
	14	19.2	22.8	24.3	25.9	26.8	27.0	29.3	32.3	36.0	40.0	45.6	51.6	56.4			29.7	5,003
D. Oligocene																		
	15	19.5	23.8	25.6	27.0	28.4	29.1	32.5	35.6	39.0	42.3	46.9	51.6	55.4	60.5		31.0	5,430

* Sample No. 5 is intermediate between B I and B II.

TABLE 1*b*. A.P.I. INTERVAL BETWEEN GRAVITY OF SUCCESSIVE FRACTIONS

	No.	*XIV Residuum*	*XIII*	*XII*	*XI*	*X*	*IX*	*VIII*	*VII*	*VI*	*V*	*IV*	*III*	*II*	*I*
A. Cap-rock Crude	1	6.6	1.5	1.2	2.4	1.7	3.9	3.8							
B. Middle Miocene															
I	2	0.8	3.3	1.3	1.2	0.9	2.8	3.3	3.9	4.4	5.8	5.5	6.1		
	7	1.4	2.8	1.3	1.2	1.1	3.0	3.1	4.5	4.0	5.8	5.8	4.9		
	5	1.9	2.6	1.3	1.1	1.0	2.8	3.1	3.9	4.0	5.3	6.1	6.3		
	9	1.6	2.4	1.4	1.2	0.7	2.8	3.1	3.0	4.2	5.4				
	10	1.5	2.8	1.2	1.0	1.2	2.7	3.1	3.6	4.0	5.7				
II	3	1.6	2.5	1.4	1.2	1.2	3.0	2.5	4.2	4.4	5.3	6.1	4.5	4.0	7.2
	4	1.9	2.7	1.5	1.2	1.0	2.5	3.3	3.8	4.8	5.3	5.9	4.8	5.6	9.4
	6	1.9	2.3	1.3	1.4	1.2	2.8	3.0	4.0	3.0	6.7	5.4	6.6	5.4	
	8	1.9	2.5	1.4	1.3	1.4	2.5	2.7	3.8	4.6	5.9	7.6	2.9		
	12	2.4	2.1	1.2	1.2	1.3	2.7	3.1	3.6	4.6	5.5				
C. Lower Miocene															
	11	3.4	1.5	1.3	1.0	0.2	2.7	3.0	3.7	4.0	4.9	6.0	6.3	3.6	
	13	3.3	1.5	1.4	1.1	0.3	2.4	3.2	3.5	3.8	4.3	5.8	5.3		
	14	3.6	1.5	1.6	0.9	0.2	2.3	3.0	3.7	4.0	5.6	6.0	4.8		
D. Oligocene															
	15	4.3	1.8	1.4	1.4	0.7	3.4	3.1	3.4	3.3	4.6	4.7	3.8	5.1	

TABLE I

CHARACTER OF CRUDE; SAMPLES GROUPED BY TYPES (*Continued*)

TABLE Ic. PERCENTAGE OF EACH FRACTION

	No.	*XIV*	*XIII*	*XII*	*XI*	*X*	*IX*	*VIII*	*VII*	*VI*	*V*	*IV*	*III*	*II*	*I*		
A. CAP-ROCK CRUDE	1	30.3	9.2	9.1	8.1	11.3	8.6	11.8	6.9	2.2	1.5						
B. MIDDLE MIOCENE																	
I	2	15.9	6.6	5.7	7.1	8.1	9.6	12.4	9.8	6.0	4.3	3.2	2.3	3.4	2.4	1.2	0.2
	7	16.3	6.8	5.8	7.1	8.7	9.7	13.3	9.3	5.7	4.8	2.8	3.1	2.8	2.8	0.8	
	5	17.2	7.3	5.7	7.0	8.7	8.3	13.4	9.9	5.5	4.0	3.1	2.8	2.8	2.5	0.9	
	9	19.0	6.8	7.7	8.0	9.9	8.5	14.6	9.2	6.4	4.4	3.0	1.0	0.8	0.6		
	10	17.7	8.4	5.7	7.7	9.7	7.1	13.6	9.9	6.3	3.9	3.1	1.7	1.3	0.9	0.7	
II	3	17.2	6.5	5.8	6.3	9.0	8.4	13.0	9.2	6.4	4.0	3.5	2.3	3.0	2.4	2.4	
	4	16.6	7.0	5.9	6.6	7.9	7.5	12.6	9.5	5.9	4.2	3.4	2.7	3.5	2.7	3.3	
	6	18.3	8.0	6.0	6.9	8.6	10.3	12.5	9.6	5.5	5.3	2.9	1.7	2.0	0.8	0.6	
	8	17.0	7.6	5.6	7.1	9.0	8.1	12.1	9.3	6.8	4.9	2.7	3.2	2.5	2.6	0.6	
	12	19.0	8.0	5.6	7.6	9.4	9.8	14.2	9.8	7.0	4.8	2.5	1.3	0.8			
C. LOWER MIOCENE																	
	11	15.0	7.7	6.0	6.1	9.2	9.9	13.4	9.5	6.1	5.0	4.0	2.8	2.1	2.7		
	13	15.6	7.1	5.8	5.2	9.6	9.2	13.0	9.9	6.4	5.2	3.3	3.1	3.1	2.6	0.3	
	14	15.5	6.5	5.4	6.0	8.1	9.0	14.9	9.7	8.3	5.8	3.9	2.7	2.1	0.9	0.3	
D. OLIGOCENE																	
	15	22.1	8.5	6.1	7.1	7.2	7.6	8.9	6.5	5.1	4.3	3.9	3.2	4.6	3.4		

TABLE Id. VISCOSITY, CARBON, AND SULPHUR

	No.	XIV	XIII	XII	XI	X	Saybolt Univ. Viscosity 70°F.	Saybolt Univ. Viscosity 100°F.	Carbon Residue Per Cent	Sulphur Per Cent
			(Viscosity at 100°F.)							
		275	250	225	200	0				
		300	275	250	225	200				
A. Cap-rock Crude	1	x	267	126	64	47	511	197	2.9	2.31
B. Middle Miocene										
I	2	x	200	91	57	45	58	48	0.4	0.17
	7	x	220	89	57	45	60	49	0.4	0.19
	5	x	195	91	58	46	64	63	0.4	0.19
	9	x	185	91	58	46	102	62	0.5	0.19
	10	x	250	91	58	46	78	58	0.5	0.25
II	3	x	245	105	62	47	62	49	0.6	0.24
	4	x	210	94	59	47	58	49	0.5	0.20
	6	x	190	91	59	46	76	56	0.5	0.21
	8	x	220	100	60	46	66	51	0.5	0.19
	12	x	215	96	59	46	92	63	0.5	0.30
C. Lower Miocene										
	11	320	150	80	54	45	60	46	0.3	0.13
	13	395	145	80	55	45	53	46	0.3	0.15
	14	395	145	80	54	45	60	51	0.4	0.14
D. Oligocene										
	15	360	170	91	57	45	66	54	0.9	0.14

TABLE II

Summary of Characteristics of Each Type

TABLE IIa. A.P.I. GRAVITY

	XIV Residuum	XIII 275 300	XII 250 275	XI 225 250	X 200 225	IX 0 200	VIII 250 275	VII 225 250	VI 200 225	V 175 200	IV 150 175	III 125 150	II 100 125	I 75 100
A. Cap-rock Crude	10.9	17.5	19.0	20.2	22.6	24.3	28.2	31.3						
B. Middle Miocene														
subtype I	17.7	19.0	21.8	23.1	24.3	25.3	28.1	31.5	35.0	39.1	44.8	51.4	56.9	
II	16.9	18.8	21.2	22.8	23.8	25.0	27.8	30.7	34.6	38.8	44.6	50.8	55.3	60.0
C. Lower Miocene	19.3	22.8	24.3	25.7	26.8	27.0	29.3	32.4	36.0	40.0	44.8	50.9	56.3	60.8
D. Oligocene	19.5	23.8	25.6	27.0	28.4	29.1	32.5	35.6	39.0	42.3	46.9	51.6	55.4	60.5

TABLE IIb. A.P.I. INTERVAL BETWEEN SUCCESSIVE FRACTIONS

	XIV	XIII	XII	XI	X	IX	VIII	VII	VI	V	IV	III	II	I
A. Cap-rock Crude	6.6	1.5	1.2	2.4	1.7	3.9	3.1							
B. Middle Miocene														
subtype I	1.3	2.6	1.3	1.2	1.0	2.8	2.9	3.8	4.1	5.7	5.6	5.5		
II	1.9	2.4	1.4	1.3	1.2	2.7	2.9	3.9	4.3	5.7	6.3	4.7	5.0	8.3
C. Lower Miocene	3.4	1.5	1.4	1.0	0.2	2.5	3.0	3.7	4.0	4.9	6.0	5.5	3.6	
D. Oligocene	4.3	1.8	1.4	1.4	0.7	3.4	3.1	3.4	3.3	4.6	4.7	3.8	5.1	

TABLE II

SUMMARY OF CHARACTERISTICS OF EACH TYPE (*Continued*)

TABLE II*c*. PERCENTAGE OF EACH FRACTION

	XIV	*XIII*	*XII*	*XI*	*X*	*IX*	*VIII*	*VII*	*VI*	*V*	*IV*	*III*	*II*	*I*	
A. CAP-ROCK CRUDE	30.3	9.2	9.1	8.1	11.3	8.6	11.8	6.9	2.2	1.5					
B. MIDDLE MIOCENE															
I	17.2	7.1	6.2	7.5	9.1	8.7	13.5	9.5	6.1	4.4	3.0	2.0	2.1	1.7	0.8
II	17.6	7.4	5.8	6.9	8.9	8.8	12.9	9.5	6.3	4.6	3.0	2.2	2.4	1.7	1.4
C. LOWER MIOCENE	15.4	7.1	5.7	5.8	9.0	9.4	13.8	9.7	6.9	5.3	3.7	2.9	2.4	2.1	0.2
D. OLIGOCENE	22.1	8.5	6.1	7.1	7.2	7.6	8.9	6.5	5.1	4.3	3.9	3.2	4.6	3.4	

TABLE II*d*. VISCOSITY, CARBON, AND SULPHUR

	(*Viscosity at 100°F.*)					Saybolt Univ. Viscosity		Carbon Residue	Sulphur
	275	*250*	*225*	*200*	*0*				
	300	*275*	*250*	*225*	*200*	*70°F.*	*100°F.*	*Per Cent*	*Per Cent*
			Seconds			*Seconds*			
A. CAP-ROCK CRUDE	x	267	126	64	47	511	197	2.9	2.31
B. MIDDLE MIOCENE									
I	x	220	90	57	45	(74)	44	0.4	0.20
II	x	218	97	60	46	71	54	0.5	0.23
C. LOWER MIOCENE	390	147	80	54	45	58	47	0.3	0.14
D. OLIGOCENE	360	160	91	57	45	66	54	0.9	0.14

A. CAP-ROCK TYPE

The A.P.I. gravity of the lighter fractions is the least of all the crudes; and greatest for the fractions heavier than 250/275°C. atmospheric pressure; the A.P.I. interval between successive fractions is the largest for the intervals between XIV–XIII, XI–X, X–IX, IX–VIII, the least for the interval XIII–XII, in all four types except for all the group C analyses, and least for the interval XII–XI, in all four types, except for a tie with analyses 10 and 12 of group B. The viscosity of the fractions 200/225° to 275/300°C. 40 mm. pressure is the greatest; and the Saybolt Universal viscosity of the crude as a whole is by far the greatest in all four types.

TABLE III

COMPOSITION IN PERCENTAGE OF FRACTIONS RECALCULATED IN TERMS OF PERCENTAGE OF 0/200°C. 40 MM. PRESSURE THROUGH RESIDUUM EQUALLING 100 PER CENT

	Residuum	275 300	250 275	225 250	200 225	0°C. 200
A. Spindletop	39.3	12.1	11.9	10.6	14.8	11.2
B. Middle Miocene	31.2	12.3	10.6	12.6	15.7	14.4
	to 32.0	13.4	11.3	13.2	16.4	17.0
C. Lower Miocene	27.8	12.4	10.3	9.9	15.4	17.1
	to 29.7	14.3	11.1	11.4	18.3	18.4
D. Oligocene	37.7	14.5	10.4	12.1	12.3	13.0

The composition in terms of the per cent of each fraction is very different from that of any of the other three types. The difference might be, but is not, caused by the absence of the lighter fractions. The composition of the heavier fractions has been recalculated in the terms of the per cent of the fractions 0/200°C. 40 mm. pressure through residuum equalling 100 per cent (Table III). The pattern of the relative proportion of those fractions of the cap-rock crude is distinctive in comparison with the pattern of the analyses of crude of the other three types.

B. MIDDLE MIOCENE TYPE

The A.P.I. gravity of the fractions from 0/200°C. 40 mm. through residiuum is distinctly higher than that of the corresponding fractions of type A; and that of the fractions from 175/200 atmos. through residuum is distinctly lower than that of the corresponding fractions of types C and D.

The pattern of the A.P.I. interval between the successive fractions is strikingly different from that of group A, and is different

from that of types C and D, particularly for the intervals XIV–XIII, XIII–XII, X–IX.

The viscosity of the fractions X–XIII is less than that for group A; and the viscosity of fractions X–XIV is greater than that of types C and D.

The percentage of carbon residue and of sulphur is consistently different from that of types A, C, and D.

The pattern of the composition in terms of percentage of each fraction is strikingly different from that of type A and significantly different from that of types C and D, although there is considerable resemblance to group C, Lower Miocene. But the content of residuum is consistently greater than that of type C and consistently less than that of type D.

The viscosity of fractions XIV and XIII distinctly differentiates the type B crude from the crudes of types C and D.

Subgroup BI is distinguished from group BII: (a) by a gravity of all fractions approximately 0.5° A.P.I. higher; (b) by a slightly lesser viscosity of fractions IX, X, XI; and by a slightly lesser content of carbon and sulphur.

The wells from which the samples of subtype BI crude was obtained lie together except for one outlying well; and similarly the wells from which the samples of group BII crude were obtained lie more or less together except for one outlying well. The difference between these two subtypes is slight. If the two types were commingled in occurrence, the differences would look apparent rather than real, but the areal grouping of the occurrence of each subtype supports the contention of the existence of two slightly different subtypes of crude.

C. LOWER MIOCENE TYPE

The A.P.I. gravity of all fractions heavier than 150/175 atmos. (IV) is consistently higher than that of the corresponding fractions of types A and B, and consistently lower than that of type D.

The A.P.I. gravity interval of 0.2–0.3 A.P.I. for the interval between the fractions 0/200°–200/225°C. 40 mm. (X–IX) characterizes this crude in comparison to all other Gulf Coast crudes which have been analyzed by the United States Bureau of Mines, except a Yegua crude from Humble, Jackson crudes from Hull and Raccoon Bend. Only one analysis of Oligocene crude from Lockport has an A.P.I. gravity interval as low as 0.4° A.P.I. for that interval. The pattern of the A.P.I. gravity intervals of those different crudes is respectively distinctive from that of the type C crude at Spindletop.

The pattern of the distribution of the A.P.I. intervals as a whole, moreover, is different from that of the other three types of crude at Spindletop.

The viscosity of the fractions 275/300 and residuum differentiates type C from all three of the other types, being lower than that for the corresponding fractions of types A and B, and being inversely higher and lower than the corresponding fractions of type D.

TABLE IV

	XIV *Residuum*	XIII 275 300	XII 250 275	XI 225 250	X 200 225	IX 0 200	VIII 250 275	VII 225°C. 250
Spindletop	Type C	3.4	1.5	1.4	1.0	0.2	2.5	3.0
Lockport	500 feet	7.8	2.0	2.2	1.9	0.4	3.4	3.7
Humble	5,300 feet	10.2	1.1	1.7	1.8	0.2	3.2	3.3
Raccoon Bend	3,500 feet	4.3	0.8	1.1	1.4	0.3	2.2	3.4
Hull	4,000 feet	8.2	2.5	1.7	1.9	0.3	2.6	3.0

The Saybolt Universal viscosity is the least among all four types.

The percentage of carbon residue is the lowest among the four types; and the percentage of sulphur is less than in types A and B.

The composition in terms of the percentage of each fraction is somewhat like that of type B, but is distinctly different from that of either type A or D.

D. OLIGOCENE CRUDE TYPE

The A.P.I. gravity of all fractions heavier than 125/150°C. atmos. is decisively higher than that of the corresponding fractions of types A, B, and C.

The pattern of the A.P.I. gravity interval is strikingly different from that of types A and B, and distinctively different from that of type C.

The viscosity of all the fractions 0/200°–275/300°C. 40 mm. (IX–XIII) is lower than that of the corresponding fractions of types A and B; and the viscosity of the fractions 200/225° to 250/275°C. 40 mm. and 275/300°C. 40 mm. is respectively lower and higher than the corresponding fractions of type C.

The content of carbon residue is distinctively higher than that of types B and C, although the sulphur content is lower than that of type C.

The pattern of the percentage of each distillation fraction is much flatter than that of types A, B, and C; that is, the different fractions are present in more nearly equal quantities than in types A, B, and C.

OCCURRENCE OF FOUR TYPES OF CRUDE OIL

TYPE A

The sample which was analyzed was a composite from an unspecified number of wells which were producing from the general depth of 800 feet. The sample therefore represents essentially the cap-rock crude oil, although there may have been inclusion of some oil from the sand which lies a short distance above the cap.

TYPE B

The type B samples came from a group of sands which lie between 2,700 and 3,400 feet.

An earlier study of the distribution of A.P.I. gravity in the flank sands indicated the presence of: (a) a seemingly inter-communicating group of sands between the depths of 2,900 and 3,400 feet; (b) a sand zone perhaps 150 feet thick at a depth of 2,750 to 2,900 feet; and (c) possibly some stray sands at those depths. That interpretation of the first group (a) was based on the two facts: (1) that in the cross section (Fig. 1) the screen settings indicate a unit "sand" zone and (2) that the A.P.I. gravity of the crude oils from that "sand" zone shows stratification under gravity, in conformity with the law that stratification under gravity tends to take place in any single reservoir which has a considerable vertical dimension. The A.P.I. gravity increases with fair regularity from 24.7° A.P.I. at the lowest point of the "sand" zone to 28.4° and 28.8° in the highest part next to the salt.

The second zone is characterized by an A.P.I. gravity of 22.4° to 23.7° A.P.I., although some wells producing from sand, which geometrically fall within the prolongation of that zone, have a gravity of 29°± A.P.I.

Six of the nine samples of type B crude came from the first zone (a); and their A.P.I. gravity conforms to the pattern of stratification of A.P.I. gravity of the crude under gravity.

Three of the nine samples came from "sands" in the prolongation of the second zone.

Areally, as can be seen from Figure 2, the samples of subtype I crude came from wells which were more or less grouped together in one area; and those of subtype II came from wells which were more or less grouped together in another area, but in each case one sample of each subtype came from a well lying out from the area of its respective subtype.

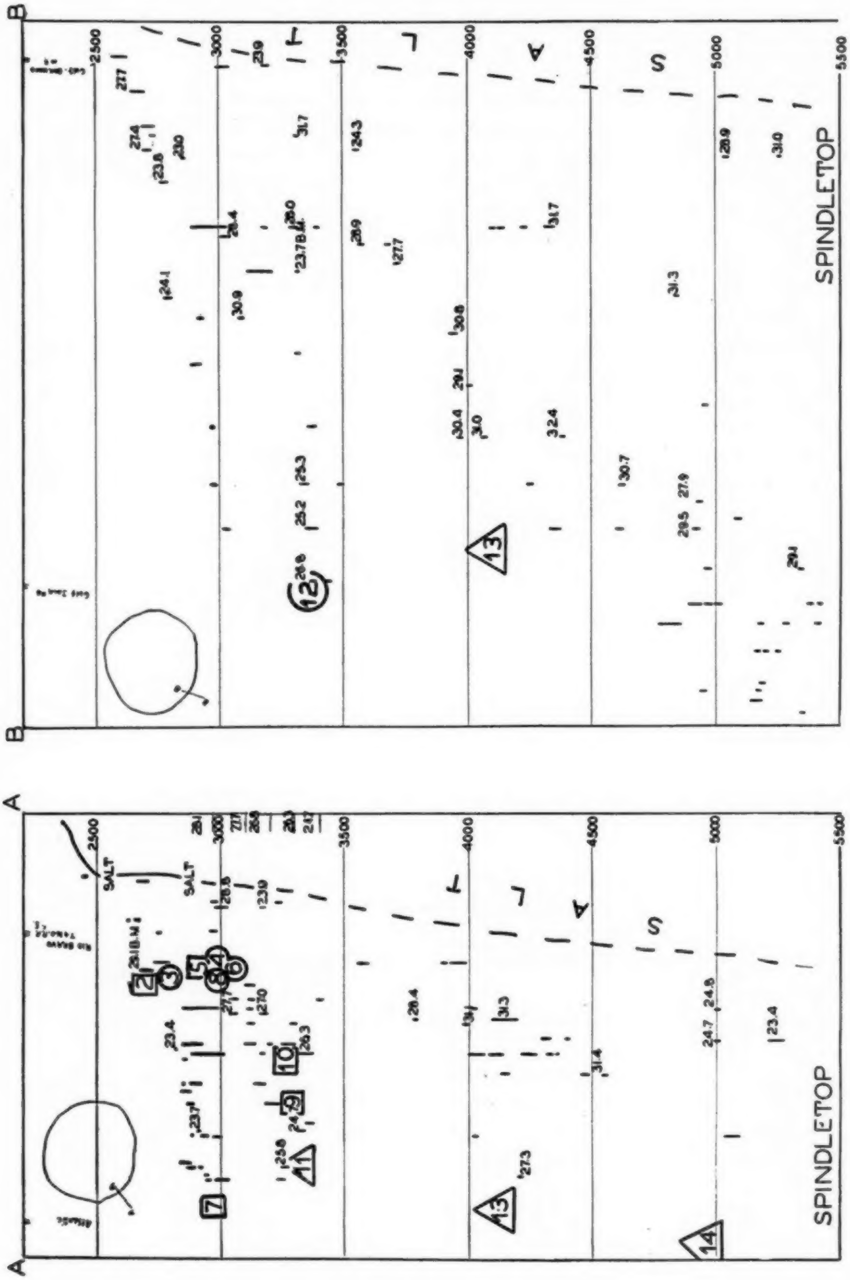

FIG. 1.—Vertical sections across southwest flank of Spindletop, showing screen settings, gravity of oil, and distribution of types of crude. Square=type BI. Circle=type BII. Triangle=type C.

TYPE C

That earlier study of the distribution of A.P.I. gravity at Spindletop also shows that from 5,300 feet to 3,400 feet the "sands" are scattered but that the A.P.I. gravity in all the "sands" lies within the range 28°–32° A.P.I.

The three samples of type C crude came from sands which are well spread vertically through that zone of high-gravity oil "sand," respectively, at depths of 3,340, 3,978, and 5,003 feet. The A.P.I. gravity of those three samples lies close to the mean A.P.I. gravity of the crude oil of that zone.

The type C samples came from the same small area as the type B oils, on the southeast flank of the dome.

The sands in which the types B and C crudes occur are Miocene. No stratigraphic differentiation of the Miocene into Lower, Middle, and Upper is made at Spindletop; and the allocation of type C to Lower Miocene and type B to Middle Miocene is not based on stratigraphic evidence.

TYPE D

The single sample of type D crude came from a well which produces from the *Discorbis* zone of the Oligocene on the south-southeast flank of the dome. The well is approximately a mile southeastward around the flank from the area from which the other samples came.

CONCLUSIONS

The following conclusions in regard to the origin of the crude oil at Spindletop seem justified by the preceding data.

The type B is indigenous to a Miocene stratigraphic zone which lies at a depth of 3,000–3,350 feet in the producing area of the southwest flank.

Subtypes BI and BII may be indigenous to slightly different horizons or sand in the same general stratigraphic zone; but, on the other hand, not enough is known about the origin and alteration of crude oil to preclude the possibility that they are some sort of differentiates within the reservoir; the samples of type BII crude came from the upper part of the reservoir; the only sample (5) of type BI from the upper part of the reservoir is intermediate in character between the two subtypes. The difference between the two types, therefore, possibly may be the effect of the stratification under gravity within the reservoir.

A type of oil of which no United States Bureau of Mines analysis is available, and which is characterized by an A.P.I. gravity of 22.4°–23.7° A.P.I., may be surmised to be indigenous to a slightly

higher Miocene stratigraphic zone whose present depth is 2,800–2,950 feet.

Type B crude has not migrated up from great depth, for its molecular character is distinctively different from that of the crudes from horizons deeper than 3,400 feet in the present producing area.

Samples 2 and 7 of type BI, and sample 3 of type BII are crude which has migrated from the 3,000–3,400-foot sand zone, to which the type B crude is indigenous, into sands of the 2,800–2,950-foot sand zone which in part is characterized by the 22.5°–23.7° A.P.I. crude. No gradation between the gravities 22.5°–24.0° A.P.I. and those of 28.2°–28.8° A.P.I. is present. We may surmise, therefore, that possibly the sands which contain the main body of 22.5–24.0° A.P.I. crude are not communicating with the stray sands which contain the migrant type B crude.

The 22.5°–24.0° A.P.I. crude in the 2,800–2,950-foot zone are surmised to be a fifth type of crude which is not represented among the United States Bureau of Mines analyses, and which is indigenous to that 2,800–2,950-foot zone.

The type C crude is indigenous to the Lower Miocene, for the character of the crude is distinctively different from that of the Oligocene Spindletop crude, for which there is an analysis (No. 15); the pattern of A.P.I. gravity interval for the type C crude is different from that of any other Oligocene crude for which a United States Bureau of Mines analysis is available; and, therefore, it would seem improbable that the type C crude seeped up from the underlying Oligocene "sands."

The crude of sample No. 11 certainly is migrant, for it is found in a sand in the stratigraphic zone to which type B crude is indigenous.

Two alternatives exist in connection with the rest of the type C crude over the 1,500 feet of its vertical range: (a) the crude may be indigenous to the whole zone; or (b) the crude may be indigenous to the lower part of the zone and be immigrant into the higher "sands." The very few, very slight differences between the character and characteristics of the analyses 11, 13, and 14 which represent crudes from depths, respectively, of 3,340, 3,978, and 5,003 feet suggest the migration of crude from "sands" low in the zone upward along fairly open fissures, for the normal variation with depth, that is, increase of the light constituents, and decrease of the heavy constituents, does not seem to be present.

The cap-rock crude must be migrant, for the origin of the cap rock precludes an indigenous origin of the crude.

That crude can not be type B, C, or D crude which has seeped into the cap rock since those three types of crude evolved approximately to its present character; for the molecular character of the cap-rock crude (type A) is distinctively different from that of the other three types. Yet the bulk of the accumulations of crude oil in the flank sands at Spindletop would seem to be of those three types; and furthermore, from Figure 1, type B crude seems to be the closest in contact with the cap rock.

Evidence as to whether the cap rock might be migrant 22.4°–23.7° A.P.I. crude from the 2,800–2,950-foot "sand" zone is not available. The high sulphur content of the cap-rock crude probably is secondary, for a moderate deposit of sulphur is known to be present in the lime cap, in the fissures and pore space of which the cap-rock crude is found. If the assumptions are made that the normal sulphur content of the crude is 0.25 per cent, that the remaining 2.06 per cent of the sulphur is secondary and in physical solution; and if the A.P.I. gravity of the crude is recalculated on a basis of only 0.25 per cent of sulphur, it would be 23.6° A.P.I. That gravity is within the range of that of the 22.4°–23.7° A.P.I. crude from the 2,800–2,950-foot zone.

A reconnaissance test of the closeness of its relationship to the other crude oils for which United States Bureau of Mines analyses are available suggested closer affinity with the Miocene crude oils of the Gulf Coast. But the test is not conclusive. The test used was the

TABLE V

No.	*Mean-Square Deviation*	*A.P.I. Gravity of Crude*	*Depth of "Sand"*	*Oil Field*	*Age*
1	0.3	32.5	1,600	Hull	Unknown (a freak, presumably migrant crude)
2	1.1	19.0	3,200	West Columbia, north side	Miocene
3	1.3	28.6	3,800	Lake Barre	Miocene
4	1.3	13.3	1,000	Saratoga	Miocene (?Pliocene)
5	1.3	17.1	1,300	Lake Pelto	Pliocene
6	1.4	17.8	4,200	Humble	Claiborne
7	1.5	24.2	2,200	Humble	Oligocene
8	1.6	20.0	3,150	West Columbia, north side	Miocene
9	1.9	21.5	3,600	Port Barre	Oligocene
10	1.9	28.2	3,700	Leesville	Miocene
11	2.0	29.1	3,300	Orange	Miocene
12	2.0	21.8	3,200	Damon Mound	Oligocene
13	2.1	21.3	3,300	Hull	Claiborne
14	2.3	21.3	2,000	Goose Creek	Miocene
15	2.4	24.3	3,900	Lockport	Miocene
16	2.4	21.0	3,150	Port Neches	Miocene
17	2.5	20.3	1,600	Danbury	Pliocene
18	2.5	21.6	1,200	Welsh	Pliocene

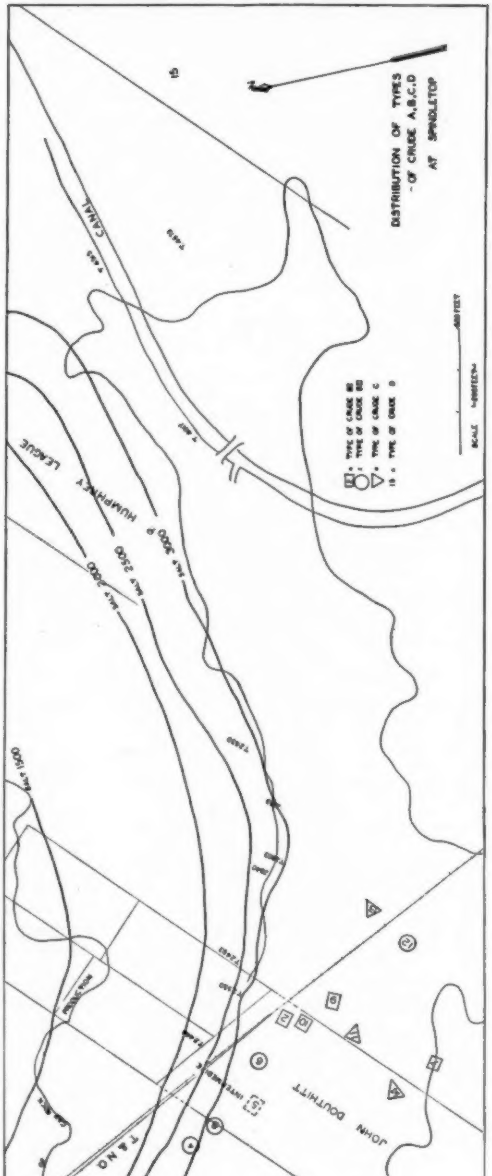

FIG. 2.—Map of southwest quadrant of flank at Spindletop, showing position of wells whose crude was represented among United States Bureau of Mines analyses, and type of crude.

mean square deviation ($=\sqrt{\Sigma\Delta^2/n}$) of the A.P.I. gravity interval for the intervals from 275/300° to 250/275°C. 40 mm. through 0/200°C. 40 mm. to 250/275 atmos. of the Spindletop cap-rock crude, from the respectively corresponding intervals of each of the other analyses with somewhat similar patterns of A.P.I. gravity intervals. The other crudes in order of increasing mean-square deviation are shown in Table V.

The closest resemblance is to a freak oil from Hull. On account of its high gravity at shallow depth, that oil presumably is a migrant; and although the geological relations are not known, the general situation at Hull suggests that the chances are somewhat better for the oil being migrant pre-Miocene oil rather than migrant Miocene oil. The next closest resemblance is that of several Miocene crudes. The data, however, do not seem to justify any definite conclusion.

THREE TYPES OF VARIATION OF CRUDE

Three types of variation of the crude must be considered: (a) variation under migration across stratification; (b) variation under differentiation, according to gravity within a single reservoir; and (c) normal variation with depth and age.

VARIATION UNDER MIGRATION ACROSS STRATIFICATION

The slightness of the change of character is the most striking feature of the variation under migration across stratification. The characteristics of the samples of migrant crude show almost no deviation from those of the samples of the assumedly non-migrant crude. The distance of migration of samples 2, 3, and 7 is of the order of only 200 feet vertically; and slight change in the characteristics perhaps should be expected. The distance of migration of samples 11 and 13 is problematic, but it is striking that the characteristics of samples 11, 13, and 14 are practically identical over a range of 1,660 feet vertically.

Statistically, the data are insufficient for a satisfactory study of the effects of migration on the character of crude oil. The samples of BI and BII are insufficient to establish the normal character of the crude in the 3,000–3,400-foot zone. The data in regard to the type C crude is insufficient to show what the mother zone of the crude is and whether either sample 13 or sample 14 represents the normal type C crude.

The trend of the suggested change seems to be in the direction from heavier to lighter crude, for there is a fair indication of a slight decrease of the content residuum and a slight decrease in the viscosity of the whole crude; and there is an inconclusive suggestion of slight

increase of the A.P.I. gravity of the individual distillation fractions during migration, and a slightly more conclusive suggestion of increase of A.P.I. gravity of the crude as a whole.

Samples 5, 9, and 10 seem to be non-migrant crude of type BI, and samples 2 and 7 the migrant crude. The respective mean values for 5, 9, and 10 are subtracted from the corresponding mean values for 2 and 7. Sample 5 was given a weight of two compared with weights of one for each of 9 and 10, for 5 comes from the upper part of the reservoir, and 9 and 10 from the lower. Crude migrant upward may have come from the lighter crude of the upper part of the reservoir; the respective values of sample 5, therefore, were subtracted from the corresponding mean for samples 2 and 7.

Sample 3 is the example of migrant crude of the BII type. The respective mean values of the latter, therefore, were subtracted from the corresponding values of 3.

Sample 11 is an example of migrant crude of type C, and sample 13 is less migrant. Sample 11, therefore, is compared with 13 and in some tables with 14; and sample 13 is compared with 14.

The respective differences by successive fractions from heavier to lighter are given in Tables VI, VII, VIII, and IX.

A suggestion of slight increase of A.P.I. gravity with migration is given in Table VI, but statistically the suggestion is not conclusive.

TABLE VI

VARIATION OF A.P.I. GRAVITY OF DISTILLATION FRACTIONS AND OF CRUDE

	Residuum	*Low Boiling*
(2 & 7)–(5, 9, 10)	+0.3, −0.2, +0.2, +0.3, +0.4, +0.4, +0.5, +1.6, +1.4, +1.4, +1.7,	+1.1
(2 & 7)–5	+0.5, −0.3, +0.2, +0.3, +0.3, +0.4, +1.5, +0.9, +1.0, +1.5,	+0.5
3–BII	+0.2, +0.1, +0.3, +0.1, +0.1, −0.1, −0.3, 0 , −0.2, +0.3, +0.4, +0.6, +1.1,	+0.7
11–13	+0.2, 0 , 0 , −0.1, −0.2, −0.3, −0.2, −0.4, −0.2, 0 , +0.6, +0.8, +1.8,	−0.9
13–14	0 , 0 , 0 , −0.2, 0 , +0.1, +0.2, +0.4, +0.2, 0 , −1.3, −1.5, −1.0,	+0.7

No systematic trend to the small changes of A.P.I. gravity interval seems to be present (Table VII).

TABLE VII

A.P.I. GRAVITY INTERVAL

(2 & 7)–(5, 9, 10)	−0.6, +0.4, 0.0, +0.1, 0.0, +0.1, +0.1, +0.6, +0.2, +0.4,
(2 & 7)–5	−0.8, +0.4, 0.0, +0.1, 0.0, +0.1, +0.1, +0.3, +0.2, +0.5, −0.5, −0.8
3–BII	−0.3, +0.1, 0.0, −0.1, 0.0, +0.3, −0.4, +0.3, +0.1, −0.4, −0.2, −0.2, −1.0, −1.1
11–13	+0.1, 0.0, −0.1, −0.1, −0.1, +0.3, −0.2, +0.2, +0.6, +0.2, +0.1
13–14	−0.3, 0.0, −0.2, +0.2, +0.1, +0.1, +0.2, −0.2, +0.2, −1.3, −0.2, +0.5

Decrease of the content of residuum with migration is indicated in Table VIII. Systematic variation of the content of the other fractions is not indicated by these data.

Slight decrease of viscosity with migration is suggested (Table IX). Statistically the suggestion is moderately satisfactory in regard to the Saybolt Universal viscosity of the crude oil as a whole, but on

the other hand, the viscosity of the 250/275°C. 40 mm. fraction shows an increase of viscosity; and the variation of the other four fractions for which viscosity is given is slight and variable in direction. The decrease in the Saybolt Universal viscosity of the crude as a whole may be surmised perhaps to be the effect of the decrease of the content of residuum under migration.

TABLE VIII

PERCENTAGE OF EACH FRACTION

	Residuum	$\frac{275}{300}$	$\frac{250}{275}$	$\frac{275}{300}$ *to* $\frac{200}{225}$	$\frac{0}{200}$ 40 *mm. to* $\frac{225}{250}$ *atmos.*	$\frac{200}{225}$ *to* $\frac{0}{50}$ *atmos.*
(2 & 7)–(5, 9, 10)	−1.3	−1.0	0.0	−1.7	+1.2	+1.6
(2 & 7)–5	−0.4	−0.6	0.0	+0.5	+1.2	−1.3
3–BII	−0.4	−0.9	0.0	−1.6	−0.5	+2.3
11–13	−0.6	+0.6	+0.2	+1.3	+0.4	−1.0
11–14	−0.5	+1.2	+0.6	+3.0	−3.0	+0.9
13–15	+0.1	+0.6	+0.4	+1.7	−3.4	+1.8

TABLE IX

VISCOSITY, CARBON, AND SULPHUR

	Viscosity $\frac{275}{300}$	$\frac{250}{275}$	$\frac{225}{250}$	$\frac{200}{225}$	$\frac{0}{200}$	*Saybolt Univ. Viscosity* 70°F.	100°F.	*Percentage* *Carbon Residue*	*Sulphur*
			Seconds						
(2 & 7)–(5, 9, 10)	x	+14	−1	−1	−1	−16	−12	−0.05	−0.02
(2 & 7)–5	x	+25	−1	−1	−1	− 7	−14	0.00	−0.01
3–BII	x	+27	+8	+2	+1	− 9	− 5	+0.1	+0.01
11–13	−75	+ 5	0	−1	0	+ 7	0	0	−0.02
11–14	−75	+ 5	0	0	0	0	− 5	−0.1	−0.01
13–14	0	0	0	+1	0	− 7	− 5	−0.1	+0.01

No systematic variation of the content of carbon residue and of sulphur is shown, although there is an inconclusive suggestion of a tendency toward a decrease of each with migration.

VARIATION UNDERLYING STRATIFICATION ACCORDING TO GRAVITY WITHIN 2,900–3,400-FOOT GROUP OF SANDS

The main difference between the samples from the upper part of the reservoir and those from the lower seems to be the slightly greater content of the very light fractions in the former. That relative enrichment of the former in the lightest fractions seems to explain the accompanying higher A.P.I. gravity and lower Saybolt Universal viscosity of the crude as a whole. But there is also a suggestion of a slight increase in the A.P.I. gravity of the light half of the distillation fractions, and a slight decrease of the A.P.I. gravity of the 250/275°C. 40 mm. fraction. There may also, or may not, be a corresponding decrease in the viscosity of the residuum and of the 275/300°C. 40 mm. fraction, for the viscosity of the residuum is not taken, and viscosity

of the 275/300°C. 40 mm. fraction is not measured beyond 400 seconds.

Statistically the data are somewhat poor; sample 5 may be balanced against 9 and 10; 4, 6, and 8 may be balanced against 12; and then tentatively the distinction between subtypes I and II may be disregarded, and 4, 5, 6, and 8 may be balanced against 9, 10, and 12. Of course possibility of confusion with a genetic difference is present, but on the other hand the difference between subtypes I and II may in part be the difference between an oil characteristic of the top of a reservoir and an oil characteristic of the lower part of a reservoir.

TABLE X

A.P.I. GRAVITY

Samples	*High Boiling Fractions* … *Low Boiling*	*Crude*
5–(9 & 10)	−0.2, +0.1, +0.1, +0.1, 0, +0.1, +0.2, +0.2, +0.8, +0.7, +0.4	+2.1
(4, 6, 8)–12	0, −0.5, −0.1, +0.1, +0.3, +0.2, 0, −0.1, +0.2, −0.3, +0.2	+2.2
(5, 4, 6, 8)–(9, 10, 12)	−0.4, −0.2, −0.3, −0.1, 0, +0.1, 0, −0.1, +0.6, +0.2, +0.5	+1.8

Slight increase of the A.P.I. gravity of the lower boiling distillation fractions and a considerably greater increase of the A.P.I. gravity of the crude as a whole are indicated (Table X). Very slight decrease of the fractions of very high boiling point is suggested.

TABLE XI

A.P.I. GRAVITY INTERVAL

Samples	*High Boiling Fractions* … *Low Boiling Point*
(5)–(9, 10)	+0.3, 0, 0, 0, 0, 0, 0, +0.6, −1.1, −0.2
(4, 6, 8)–12	−0.5, +0.4, +0.2, +0.1, −0.1, −0.1, −0.1, +0.2, −0.5, +0.5
(4, 5, 6, 8)–(9, 10, 12)	0, +0.1, +0.1, +0.2, +0.1, −0.2, −0.1, +0.4, −0.2, +0.3

No systematic variation of the interval is indicated in Table XI.

TABLE XII

VARIATION OF PERCENTAGE OF DISTILLATION FRACTIONS

	Residuum	$\frac{275}{300}$ *to* $\frac{200}{225}$,	$\frac{0}{200}$ *to* $\frac{225}{250}$ *40 mm.*,	$\frac{220}{225}$ *to* $\frac{0}{50}$ *atmos.*
(5)–(9, 10)	−0.9	−2.8	+0.3	+3.3
(4, 6, 8)–12	−1.5	−1.8	−4.0	+7.5
(4, 5, 6, 8)–(9, 10, 12)	−1.0	−2.5	−1.4	+4.9

A marked increase of the very light distillation fractions and a decrease of all the other fractions are indicated in Table XII.

Decrease of the viscosity of the crude as a whole, and of the 250/275 40 mm. fraction is indicated in Table XIII. No change, or systematic change, in either direction is shown by the 225/250, 200/225, and 0/200°C. 40 mm. fractions.

TABLE XIII

VISCOSITY, CARBON RESIDUE, AND SULPHUR

	Viscosity of Fractions					Saybolt Univ. Viscosity of Crude		Percentage	
	275/300'	250/275'	225/250'	200/225'	0/200'	70°	100°	Carbon Residue	Sulphur
(5)-(9, 10)	x	−22	0	0	0	−26	+3	−0.1	−0.03
(4, 6, 8)-(12)	x	− 8	−1	0	0	−25	−9	0	−0.10
(4, 5, 6, 8)-(9, 10, 12)	x	− 8	+1	+1	0	−25	−6	−0.0	−0.07

A suggestion of a tendency for an extremely slight decrease of the content of carbon residue is suggested.

Slight decrease of the content of sulphur is suggested.

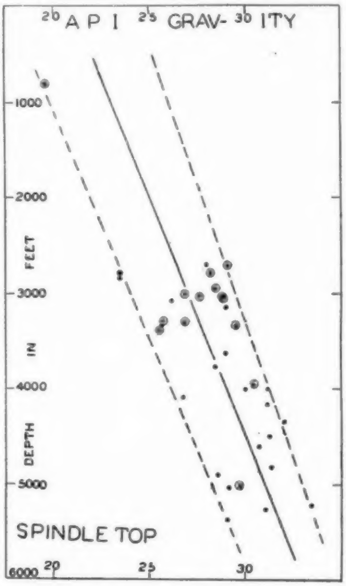

FIG. 3.—Variation of A.P.I. gravity of Spindletop crude with depth.

VARIATION WITH DEPTH

Tendencies are shown for increase (1) of the A.P.I. gravity of the crude and of all the distillation fractions except the 100/125 and 75/100 atmos. fractions; and (2) of the percentage of the lighter half of the distillation fractions, with increasing depth of the crude.

Decrease with depth is shown (1) by the percentage of heavier

fractions, and (2) by the viscosity of the heavier fractions, but, rather surprisingly, the Saybolt Universal viscosity of the crude does not show a decrease parallel with the decrease of the heavier half of the fractions, and with increase of the A.P.I. gravity with depth.

This variation with depth among these samples of Spindletop crude oil presumably combines: (1) the normal variation under the depth factors of temperature and pressure; and (2) normal variation with stratigraphic age, for with the exception of the cap-rock crude, which is of undetermined age, the arrangement of the samples according to depth is also arrangement according to stratigraphic age.

Irregularities are shown which in part may be the effect of the idiosyncrasies of individual crudes, and of effects of migration.

TABLE XIV
A.P.I. GRAVITY

Depth	Residuum	275/300	250/275	225/250	200/225	0/200	40 mm.	250/275	225/250	200/225	175/200	150/175	125/150	100/125	75/100	Whole Crude
800	10.9	17.5	19.0	20.2	22.6	24.3		28.2	31.3							19.7
2,750	17.4	18.6	21.5	22.9	24.1	25.1		28.0	31.0	35.0	39.4	45.0	50.7	56.0		28.6
3,100	17.1	19.0	21.2	22.9	24.1	26.2		27.9	31.2	34.7	38.9	44.6	51.0	56.0		27.3
3,340	19.4	22.8	24.3	25.6	26.6	26.8		29.3	32.3	36.0	40.0	44.9	50.9	57.2		29.5
3,978	19.2	22.8	24.3	25.7	26.8	27.1		29.5	32.7	36.2	40.0	44.3	50.1	55.4		30.4
5,003	19.2	22.8	24.3	25.9	26.8	27.0		29.3	32.3	36.0	40.0	45.6	51.6	56.4		29.7
5,430	19.5	23.8	25.6	27.0	28.9	29.1		32.5	35.6	39.0	40.0	46.9	51.6	55.4		31.0

A distinct tendency is shown for the crudes at relatively greater depth to have a higher A.P.I. gravity; and the tendency holds both for the individual fractions and for the crude as a whole (Table XIV).

TABLE XV
A.P.I. GRAVITY INTERVAL

800	6.6	1.5	1.2	2.4	1.7	3.9	3.1							
2,750	1.2	2.9	1.3	1.2	1.0	2.9	2.9	4.0	4.4	5.5	5.8	5.3	4.0	7.2
3,100	1.8	2.5	1.3	1.2	1.2	2.2	3.1	3.8	4.1	5.7	6.2	5.1	5.5	
3,340	3.4	1.5	1.3	1.0	0.2	2.7	3.0	3.7	4.0	4.9	6.0	6.3	3.6	
3,978	3.3	1.5	1.4	1.1	0.3	2.4	3.2	3.5	3.8	4.3	5.8	5.3		
5,003	3.6	1.5	1.6	0.9	0.2	2.3	3.0	3.7	4.0	5.6	6.0	4.8		
5,430	4.3	1.8	1.4	1.4	0.7	3.4	3.1	3.4	3.3	4.6	4.7	3.8	5.1	

No clear suggestion of systematic variation of the A.P.I. gravity interval with depth is shown in Table XV. A very irregular tendency for the interval of the deeper crudes to be slightly less than in the higher crudes is shown, but probably it is not significant.

A tendency for increase of the lighter half of the fractions with increasing depth, and for corresponding decrease of the lighter half is distinctly shown, although the migrant crude at 2,750 feet, and the Oligocene crude at 5,430 feet do not fit into the picture (Table XVI).

A tendency for the viscosity of the distillation fractions between

TABLE XVI

PER CENT OF DISTILLATION FRACTIONS

Depth	I *Residuum*	II $\frac{275}{300}$ *to* $\frac{200}{225}$,	III $\frac{0}{200}$ *to* $\frac{225}{250}$,	IV $\frac{200}{225}$ *to* $\frac{0}{50}$	I & II	III & IV
800	30.3	37.7	29.5	1.5	68.7	31.3
2,750	16.5	27.5	37.4	17.3	44.6	55.3
3,100	17.6	29.7	37.7	14.2	47.7	52.3
3,340	15.0	29.0	38.9	16.6	44.2	55.8
3,978	15.6	27.7	38.5	17.6	43.8	56.2
5,003	15.5	26.0	41.9	15.7	41.9	58.1
5,430	22.1	28.9	28.3	19.4	51.7	48.3

TABLE XVII

VISCOSITY, SULPHUR, AND CARBON RESIDUE

Depth	*Viscosity* $\frac{275}{300}$	$\frac{250}{275}$	$\frac{225}{250}$	$\frac{200}{225}$	$\frac{0}{200}$ 40 *mm.*	*Saybolt Univ. Viscosity* 70°	100°	*Percentage Carbon Residue*	*Sulphur*
800	x	267	126	64	47	511	197	2.9	2.31
2,750	x	233	98	60	46	60	49	0.5	0.20
3,100	x	211	93	59	46	75	56	0.5	0.21
3,340	320	150	80	54	45	60	46	0.3	0.13
3,978	395	145	80	55	45	53	46	0.3	0.15
5,003	395	145	80	54	45	60	51	0.4	0.14
5,430	360	170	91	57	45	66	54	0.9	0.14

0° and 300° C. at 40 mm. pressure to decrease with depth is shown, but again the Oligocene sample does not quite fit into the scheme (Table XVII). The Saybolt Universal viscosity of the crude varies irregularly and has no systematic trend of variation in either direction.

No systematic trend of variation of the carbon residue or of the sulphur is evident.

RETROSPECT

Some of the results of this study are of broad general importance in connection with the problems of the origin of petroleum.

In connection with the problem of source beds it has seemed to the writer most important to trace a restricted type of petroleum back to a restricted stratigraphic zone and then to study the organic content and the general character of the beds of that zone in the attempt to recognize what it is that makes a source bed. *A priori*, not all organic material is necessarily potential mother material for petroleum; a study of the organic content of the sediments need necessarily show only the organic content and need not show the content of potential mother material for petroleum; all the material which can be transformed into petroleum may have already been transformed; and the study of the mother material may have to be an indirect study of residual material. This method of attack has not been greatly

used, for the reason, perhaps, of the absence of reliable criteria for definite identification of a distinctive petroleum with a restricted stratigraphic horizon.

The identification of certain distinctive petroleums respectively with certain restricted stratigraphic zones seems to have been accomplished by the present study for the local area of the Spindletop salt dome.

The source beds of the type B crude, presumably, lie within a vertically narrow stratigraphic zone, which lies at a depth of 2,950–3,500 feet in the area of the flank oil field, for they seem to be delimited by the zone of the $23° \pm$ A.P.I. crude immediately above; and by the zone of the 28°–32° A.P.I. crude immediately below.

The source beds of the $23° \pm$ A.P.I. crude must lie within the general stratigraphic zone which lies at a depth of 2,750–2,900 feet in the area of the flank oil field at Spindletop, for they are delimited definitely below by the zone of the type B crude.

The source beds of the type C crude must lie somewhere in the stratigraphic zone between the depths of 3,500 and 5,000 feet in the area of the flank oil field at Spindletop, for they are delimited by the zone of the type B crude above and the Oligocene below.

A suggestion of a possible technique for the distinctive identification of different crude oils is given by the results of this study. The use of the A.P.I. gravity interval between the successive 25° C. distillation fractions in conjunction with the A.P.I. gravity of those fractions, with the viscosity of certain fractions, with the viscosity of the crude as a whole, and to a lesser extent, with the percentage content of each of those fractions, may prove to be a powerful method for the identification of crude oils from different source beds. The results of this technique in its application at Spindletop seem definitely successful. But the general applicability of the method needs to be tested critically by a broader study of it.

Migration upward from some stratigraphically and actually deeper source beds is a common explanation, more favored in Europe than in this country, of the source of any particular crude. The psychological reason for the attractiveness of that explanation lies, perhaps, in the falseness of our concept of the characteristics of source beds, as the actual source beds do not correspond with the conventional concepts of what source beds should look like. Many geologists tend, therefore, to attribute the source of the oil to deeper beds which do correspond with those conventional concepts of source beds, or to unknown deeper beds.

The differences which are observable between the shallower and

younger crude oils, and the deeper and older crude oils, at the same time are explained as the effects of evaporation of the lighter constituents, or as the effects of reactions with oxygen, sulphur, or sulphates of water in contact with the oil during or after the migration.

But Spindletop provides a case of an oil field in which no upper one of the four types of crude, A, B, C, or D, has been derived by upward migration without essential change of character from any lower one of those types. Slight migration of crude oil of types B and C was observed; but the distinctive individuality of each type shows definitely that it is not essentially unchanged migrant crude of any one of the other three types; for the molecular composition of each of those types is distinctively different from that of the other three types.

Not one of those types, on the other hand, can have been formed by any simple alteration from any other of those three types. Simple evaporation of lighter constituents from the relatively shallower crude oils will not explain the difference in character between relatively shallower and relatively deeper crude oils, for the heavier half of the crude shows the distinctive molecular individuality of each of those several types of crude. Reactions with sulphur, presumably, have been negligible, except in the cap-rock crude (type A), for the type B crude has only 0.07 per cent more sulphur than type C and type D crude; and the sulphur content of type C is the same as that of type D. Oxidation is an equally doubtful explanation of those differences, for the recent United States Bureau of Mines studies show that the effects of severe oxidation produce insoluble asphalt but produce no appreciable change in the character of the rest of the oil. Any alteration which would produce any one of those types from the other type must involve a complicated and drastic change in the fundamental molecular character of the crude; a change which in part would vary linearly in the intensity of its effect on progressively lighter fractions, and which in part would capriciously vary in intensity from fraction to fraction. Explanation of the differences between those different types of crude oil by invocation of alteration of migrant crude of the one type to form another, at present is much more improbable than the explanation of derivation of the crude oils respectively from different source beds.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 644-650, 2 FIGS.

BELLE ISLE SALT DOME, ST. MARY PARISH, LOUISIANA[1]

DONALD C. BARTON[2]
Houston, Texas

ABSTRACT

A detailed torsion-balance survey has been made and a series of wells has been drilled since publication of Vaughan's paper in *Geology of Salt Dome Oil Fields*. The exploration now shows a subcircular dome 8,000–6,000 feet in diameter, the center of the dome in the northwestern part of South Pond, and a moderately thick cap at a depth of 350–700 feet over the south half of the dome.

LOCATION

Belle Isle salt dome is in Ts.17–18 S., R.10 E., in St. Mary Parish, Louisiana, 15 miles south-southwest of Morgan City.

Belle Isle is reached by boat, via the Atchafalaya River, Wax Bayou, and other bayous from Morgan City.

HISTORY

The exploration of Belle Isle began in 1896, when Captain Lucas drilled his well on the west edge of the island. The presence of the salt was disclosed by his second well, which was drilled in 1897 on the northern part of the island. A series of wells, inclusive of thirteen wells of the Gulf Company, was drilled in 1897 and 1898, to outline the salt under that northern part of the island. Two unsuccessful attempts were made to sink shafts into the salt and to mine the salt.

The New Orleans Mining and Milling Company (American Salt Company) drilled several wells during 1906, and I. N. Knapp drilled three oil tests during 1907–08.

The six "Syndicate" wells were drilled in search of sulphur by Captain Lucas during 1916–17 for a syndicate of New York capitalists.

The Union Sulphur Company drilled a series of ten sulphur and oil tests during 1921–25.

The Freeport Sulphur Company made a geophysical survey of the dome with torsion balance and then, during 1929–30, drilled a series

[1] Manuscript received, February 14, 1935.

[2] Humble Oil and Refining Company.

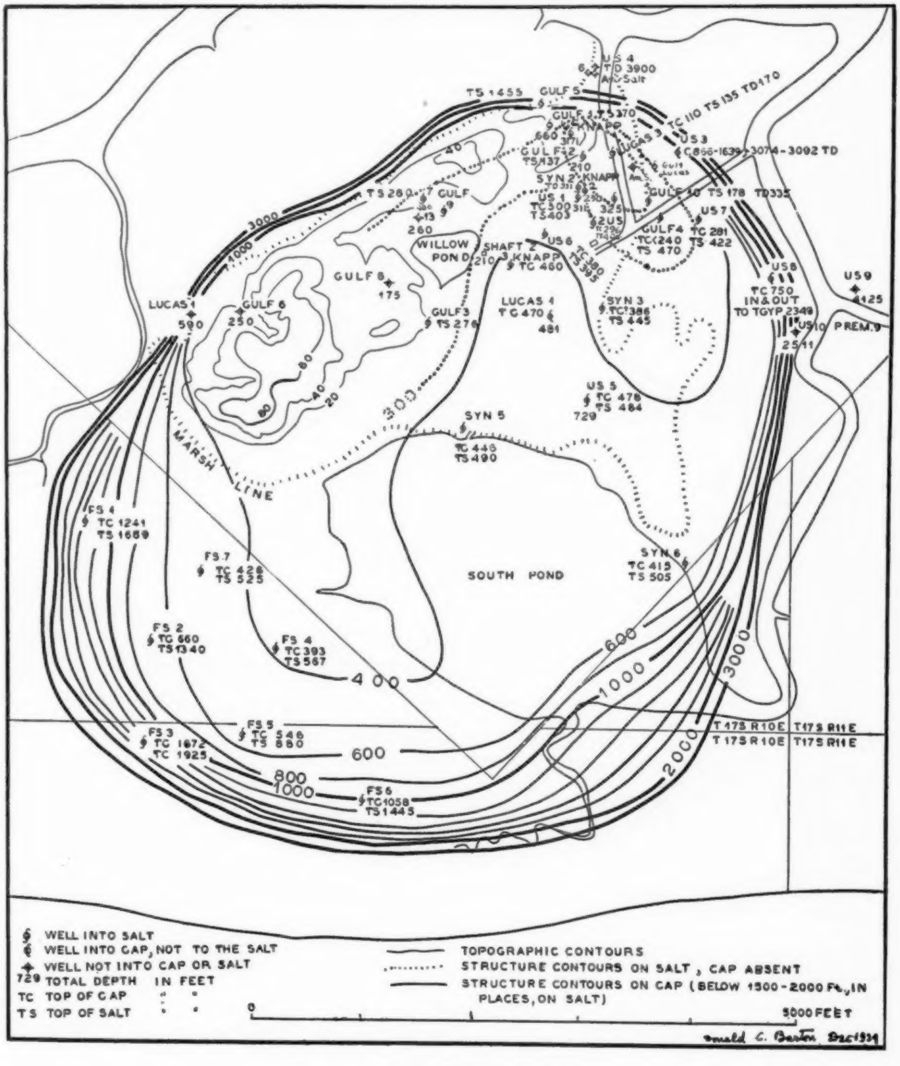

FIG. 1.—Map of Belle Isle dome.

of seven sulphur tests in exploration of the southwestern third of the dome.

The knowledge of the dome through the Union Sulphur Company's No. 8 is summarized by Vaughan.[3] The purpose of the present paper is to supplement that paper with the newer knowledge from the subsequent explorations.

The maps of the dome were found, by the Freeport Sulphur Company, to be poor; the location of the wells on the maps was most chaotic. The company resurveyed the dome, surveyed all well sites which could be found, and attempted to trace as accurately as possible the location of the other old tests. The accompanying map is presumed, therefore, to be as accurate as it is possible to make a map of Belle Isle. Many of the locations on Vaughan's map (his Figure 2) are seriously out of place.

WELL DATA

The summarized data of the Union Sulphur Company oil and sulphur tests and of the Freeport Sulphur Company are given in Table I.

TABLE I

SUMMARIZED DATA OF UNION SULPHUR COMPANY AND FREEPORT SULPHUR COMPANY WELLS

Name	*No.*	*Depth of Cap (Feet)*	*Depth of Salt (Feet)*	*Total Depth (Feet)*	*Remarks*
U.S.Co.	1	300	403	433	
U.S.Co.	2	296	406	2,200	Cap: 300–320 soft limestone 320–400 limestone and gypsum, trace sulphur
U.S.Co.	3	866–1,639 3,074	—	3,092	
U.S.Co.	4	—	—	3,900	
U.S.Co.	5	478	484	728	
U.S.Co.	6	380	395	643	
U.S.Co.	7	281	422	499	
U.S.Co.	8	750	—	—	In and out of cap from 750 to 2,349; top gypsum, 2,349
U.S.Co.	9	—	—	4,125	
U.S.Co. (also Premier 9)	10	—	—	2,511	
F.S.Co.	1	1,247	1,689	1,853	Cap: hard lime-rock with calcite veins, mostly impervious
F.S.Co.	2	660	1,304	1,321	Cap: Same as in No. 1
F.S.Co.	3	1,672	1,925	1,940	Cap: same as Nos. 1 and 2
F.S.Co.	4	393	567	828	Cap: lime-rock and a little gypsum and anhydrite
F.S.Co.	5	546	873	880	Cap: same as in No. 4
F.S.Co.	6	1,058	1,445	1,445	Cap: broken lime-rock and calcite; voids filled with sandy shale
F.S.Co.	7	426	576	580	Cap: broken lime-rock, calcite, and gypsum; voids filled with sandy shale

[3] See References at end of article.

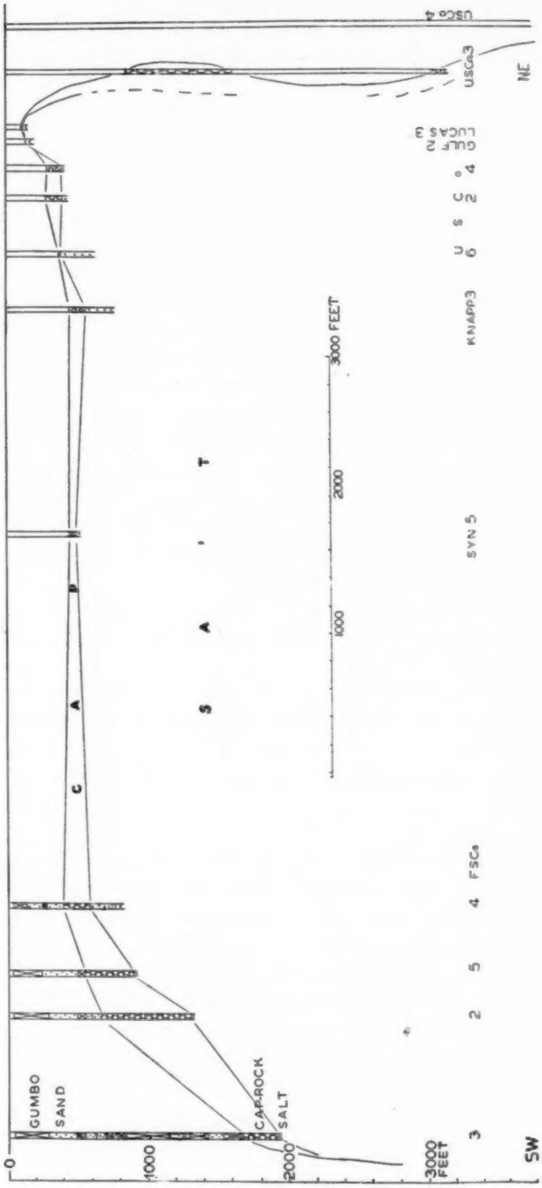

FIG. 2.—Cross section, Belle Isle dome.

A few showings of sulphur and no showings of oil or gas were obtained in the Freeport Sulphur Company's wells, and also in the wells of the Union Sulphur Company.

GEOLOGY OF DOME

The Belle Isle dome is a very shallow, medium-large, subsidiary spine type of dome.

Most of the top of the dome lies at a depth of 300–500 feet and is covered by cap rock. The top of the cap rock slopes southward; and the thickness of the cap increases in the same direction.

A spine of salt rises at the north end of the dome to within almost 100 feet of the surface, and within 60 feet of the general marsh level. The spine is bare of cap, which wedges out against the base of the spine. The upthrust of the spine has domed the surface to form the northern surface mound.

The presence of a second and larger spine is indicated by the larger southwestern topographic mound. The wells show a saddle between the northern spine and the beginning of this southwestern spine. Only one very shallow well which did not reach cap or salt by a total depth of 250 feet has been drilled on this mound, rather well down its northwest flank.

According to the writer's interpretation these subsidiary spines, and the similar spines at Vinton and New Iberia, are the result of localized uplift of the dome.

The slope of the upper flank, above 3,000 feet, is steep-to-vertical in the northeastern half of the dome, and is relatively gentle in the southwestern half of the dome. The Gulf Production Company's No. 5 on the north went through several stringers of salt between the depth of 600 feet and the top of the salt at a depth of 1,500 feet. The Union Sulphur Company's No. 3 on the northeast edge went through a 773-foot overhang of cap between the depths of 866 and 1,639 feet, and went into cap again at a depth of 3,092 feet. The same company's No. 8 on the east flank went in and out of cap rock from a depth of 750 feet to the top of the gypsum cap at a depth of 2,349 feet. The data of the torsion-balance survey qualitatively suggest a steep-to-vertical edge of the salt-cap mass on the northwest flank. The data from the Freeport Company's seven tests show a gentle slope of the top of the cap down to a depth of 1,000 feet, and a slightly steeper slope down to a depth of 1,600 feet. The relatively gentle slope is indicated by quantitative calculations from the data of the torsion-balance survey to extend across the southeast octant of the flank. A moderately steep slope from 1,600 feet down to 3,000 feet is indicated

by those calculations. The steep slope on the northeast and the gentle slope on the southwest raise the surmise that the vertical axis of the dome may be slightly tilted.

REGIONAL SYMMETRY

A curious symmetry is shown by Belle Isle in reference to the other domes of the Five Islands. The significance of the symmetry is not yet clear.

Those five domes have common features distinguishing them from the other domes of the Gulf Coast. The salt cores rise slightly above, to, or almost to, the general level of the surrounding country. The diameter of the domes is not quite 2 miles. All of the domes have a higher salt-dome mound than is common for the Gulf Coast domes. The northwestern four domes are spaced equidistantly; and the distance between the two southeastern domes is approximately twice that interval. The Five Islands have a definite, faintly curvilinear alignment.

The curious symmetry, which may or may not have significance, consists in the following distribution of features.

1. A cap several hundred feet thick is present on the end domes, Belle Isle and Jefferson Island, but no cap is present on the central three domes.

2. Both the end domes have a subsidiary spine or spines which rise above a general top of the dome at a lower depth; the spines are on the side of the dome near the center of the sequence of the Five Islands; and the lower general level of the top of the dome, and the cap, are on the far side.

3. Belle Isle and Jefferson Island have central-basin lakes unlike the other domes of the Five Islands, although the thick pocket of Recent clays under the present crest of the Côte Blanche mound indicates the presence of a central basin in the recent geologic past. A salt spine seems to have projected up into a series of gravel beds and to have been dissolved gradually. The basin above the dissolving salt spine was filled by several hundred feet of Recent surface clays, which can be recognized both from drilling data and torsion-balance data as forming a deep pocket in the gravels. But a similar explanation of the Lake Peigneur at Jefferson Island and South Pond at Belle Isle does not seem applicable.

4. The topographic mounds at Belle Isle and Jefferson, which are coextensive only with the salt spines, are smaller and lower than those of Avery Island, Weeks Island, and Côte Blanche, which are coextensive with the whole dome.

The line of the Five Islands is parallel with the writer's Iberian structural axis, and is the backbone of the writer's Iberian shallow-dome area.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 651-688, 15 FIGS.

POST-FLEMING SURFACE FORMATIONS OF COASTAL SOUTHEAST TEXAS AND SOUTH LOUISIANA[1]

JOHN DOERING[2]
Dallas, Texas

ABSTRACT

The paper gives a general discussion of the surface formations and surface geology of the post-Fleming belt lying between the coast and the outcrop of the Fleming in southeast Texas and south Louisiana. Data and discussion are presented under four main heads, Physiography, Stratigraphy, Origin and History, and Structure.

Under Physiography it is shown that the present physiography indicates the general features of the geology of the area, that is, the subdivision of the post-Fleming group into four formations, Recent, Beaumont, Lissie, and Willis, and the general structure and interrelations of these formations.

Under Stratigraphy the present subdivision is correlated with earlier classifications. The formations are described. The Willis, which is a new formation roughly equivalent to the old Lafayette and Reynosa of this area, is named, subdivided into three members, and described in detail. Its relation to the Goliad formation of south Texas is discussed.

Under Origin and History the deposition of these formations is credited to the ancestors of the present major streams of the coast. The peculiar stratigraphic and structural interrelations of the post-Fleming formations are attributed to cycles of deposition separated by tilting movements which affected this part of the coastal plain at intervals.

Under Structure the regional structure of the formations, local irregularities, methods of mapping, and the relation of surface to subsurface structure are discussed.

INTRODUCTION

This paper presents some of the general results of an examination of the post-Fleming surface formations of coastal southeast Texas and south Louisiana. Physiography, stratigraphy, and regional structure are described and conclusions are drawn as to the origin and history of the formations. Some of the local irregularities in surface structure are pointed out and discussed.

AREA

The area examined extends about 500 miles along the Gulf Coast, from the Colorado River in Texas to the Pearl River at the eastern

[1] Read before Houston Geological Society at Houston, Texas, on January 17, 1935. Manuscript received, February 18, 1935.

[2] Geologist, John R. Black and J. L. Collins, 1401 Tower Petroleum Building. The original material presented in this paper was collected during examinations made for John R. Black of Dallas and J. L. Collins of Corsicana, Texas. The writer wishes to express appreciation for permission to publish this paper. Assistance and criticism of George Sawtelle and Donald Barton and other members of the Houston Geological Society during the writing of the paper are also gratefully acknowledged.

boundary of Louisiana. It extends 75–100 miles into the interior, from the coast to the outcrop of the Fleming formation.

PHYSIOGRAPHY AND REGIONAL GEOLOGY

The general plan of the surface geology of this coastal belt is relatively simple and is well shown by the physiography of the area, as illustrated in Figure 1. This diagram, which gives a view in perspective of the Texas and Louisiana coast northeast of the Colorado River, shows a division of the Coastal Plain into two distinct parts, an interior erosional plain covering the outcrop of the Fleming and older formations, and a series of depositional plains near the coast, covering the post-Fleming formations. These young depositional plains reveal not only the areal extent of the various members of the post-Fleming group, but also their general structure and inter-relations.

The interior erosional area owes its character as a plain to the fact that erosion has bevelled the formations and brought the high points of topography down to fairly uniform levels. Its surface is completely dissected by small streams and is now probably at its maximum stage of relief and ruggedness. Continued erosion will tend to decrease its relief and produce an approach to a peneplain.

The plains of the post-Fleming area, on the other hand, are due to the presence of depositional surfaces which have not yet been destroyed by erosion. The oldest of the post-Fleming formations has been considerably dissected, but the tops of its ridges are dip-slopes which approximate the original surface of the formation. The younger post-Fleming formations have scarcely been touched by erosion throughout large areas, and their original surfaces can readily be reconstructed, as shown in the figure. Continued erosion in this division of the coastal plain will increase the local relief and ruggedness of topography, and will eventually bevel the formations and add this area to the interior erosional plain.

The post-Fleming area is shown to be subdivided into four units —Recent, Beaumont, Lissie, and Willis—each of which is represented by a formation and a physiographic division. The Recent deposits occupy the river valleys and occur along the coast line as beach and delta deposits. The Beaumont formation covers the Beaumont plain, the Lissie formation covers the Lissie plain, and the Willis formation holds up the ridges of the hilly, cuesta-like belt between the Lissie and the Fleming areas.

The Lissie plain, as shown by the contours drawn on its surface, consists of a series of coalescing river-built fans deposited on the

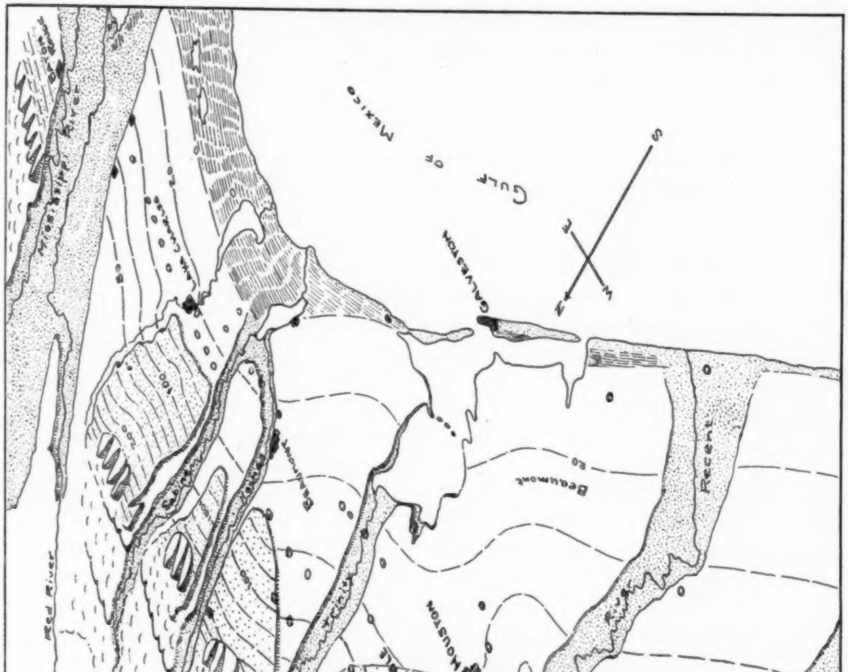

FIG. 1.—Texas and Louisiana coast northeast of Colorado River.

coastward side of stream gaps cut through the Willis cuesta. Terrace deposits which are continuous with the coastal Lissie pass up through the stream gaps and represent remnants of the valley deposits made by the streams which built the Lissie fans.

The Beaumont plain, like the Lissie plain, consists of a series of coalescing river-built fans. During its deposition the stream gaps were cut down into the Lissie. The present streams have cut trenches or valleys down into the Beaumont.

The Willis formation, in the opinion of the writer, had an origin similar to that suggested for the Lissie and Beaumont, the discharge of sediments occurring through stream gaps in a cuesta of the first hard formation, the Catahoula, and the deposition occurring on a comparatively flat erosional plain developed on the Fleming. A comparison of the rates of dip of the Fleming and Willis suggests that the Willis overlapped the Fleming along a strike line through Madisonville. The stream gaps might have been located along this line. Erosion has removed such gaps, if they existed, and the interior extensions of the Willis.

The rate of dip which can be measured on the surface exposures of the Fleming and older formations in this area is approximately 50 feet per mile, while that of the Willis is between 10 and 25 feet per mile. The slope of the Lissie plain is about 5 feet per mile, that of the Beaumont about 2 feet per mile, and that of the Recent deposits in the river valleys of the coast is one foot per mile or less.

The contours on the Lissie and Beaumont in the figure have been constructed from topographic maps and represent the regional surface structure of these formations. Irregularities such as that at Humble indicate uplift since the deposition of the surface formation.

STRATIGRAPHY

PRESENT SUBDIVISION

Table I, which is a modification of part of a table given by Plummer,[3] gives the subdivision of the post-Fleming used by the writer in this paper, and the probable correlation with the southwest Texas section.

The following list gives the general descriptions of the various formations appearing at the surface in southeast Texas and south Louisiana.

RECENT Alluvial deposits of river valleys, beach deposits, et cetera.
BEAUMONT Clays, calcareous clays, sandy clays, and fine sands

[3] F. B. Plummer, in "The Geology of Texas," Vol. 1, *Univ. Texas Bull. 3232* (1933), pp. 530 and 749–63.

LISSIE	Fine light-colored sands and clayey sands
WILLIS	Reddish sands and gravelly sands
GOLIAD (?)	Sandstones and bright-colored clays
FLEMING	Calcareous clays, some thin irregular sandstones

The formations listed rest on each other unconformably and disconformably. Figure 3 gives sections at various points along the coast which show the surface relations of the formations and the suspected presence of an overlapped equivalent of the Goliad formation.

TABLE I

Age	*Group*	*Formation*	*Members Southwest Texas*	*Members Southeast Texas*
Recent	Recent	Recent	Recent	Recent
Pleistocene	Houston	Beaumont	Beaumont	Beaumont
		Lissie	Lissie	Lissie
Pliocene	Citronelle (?)	"Willis" (unnamed Pliocene)	Present?	Hockley Mound Willis Sand Willis Gravel
		Goliad	Labahia Lagarto Creek Lapara	Present?
Pliocene and Miocene	Fleming	Lagarto	Lagarto	Fleming
		Oakville	Oakville	

The name "Willis" is a new name proposed by the writer in this paper for the formation of sand and gravelly sand referred to by Plummer as "unnamed Pliocene sand" and "Upper Citronelle sands."[4]

PREVIOUS SUBDIVISIONS

In the published literature on this group of formations there is some confusion and disagreement, as shown in Table II. Not all of the many different classifications are given, but the more important variations in subdivision and usage are represented.

Kennedy gave the upper clay formation the name "Beaumont" after the city of that name in southeast Texas. The name has been accepted in general usage, and has appeared in practically all subsequent subdivisions.

Kennedy's name for the middle formation of fine sands, "Columbia sands," which was borrowed from the Atlantic Coast section, has disappeared and has been replaced by the name "Lissie" proposed by

[4] F. B. Plummer, *op. cit.*, pp. 749–63.

TABLE II

Kennedy[5] *1903* *SE. Texas*	*Deussen*[6] *1924* *SW. Texas*	*Barton*[7] *1930* *SE. Texas*	*Howe*[8] *1933* *Louisiana*	*Plummer*[9] *1933* *Texas*	*Weeks*[10] *1933* *SW. Texas*	*Doering* *1935* *SE. Texas and S. Louisiana*
Beaumont	Beaumont	Beaumont	Beaumont and/or Port Hudson	Beaumont	Beaumont	Beaumont
Columbia	Lissie			Lissie (Reynosa)	Upper Lissie	Lissie (Citronelle, Port Hudson)
Lafayette	Reynosa	Lissie	Citronelle (?)	Unnamed Pliocene (Citronelle)	Lower Lissie	Willis
				Goliad	Upper Lagarto	Goliad (?)

Deussen. The type locality is at the town of Lissie, in Wharton County, Texas.

The lowest division, of gravelly sands, was named "Lafayette" by Kennedy, after a type locality in Lafayette County, Mississippi. This locality is far in the interior of Mississippi in an area of Tertiary Wilcox. The name has been applied to so many gravelly deposits that it has lost specific meaning and has been discarded.

Deussen, following the usage of Dumble and Trowbridge,[11] applied the name "Reynosa" to the basal gravelly formation, including with it part of the calcareous sandstone section which has later been separated as the Goliad formation. The name "Reynosa" was widely used until the type locality at Reynosa, Mexico, was placed in the Lissie formation.[12]

[5] C. W. Hayes and William Kennedy, "Oil Fields of the Texas-Louisiana Gulf Coastal Plain," *U. S. Geol. Survey Bull. 212* (1903), pp. 12–31.

[6] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *ibid.*, *Prof. Paper 126* (1924).

[7] Donald C. Barton, "Surface Geology of Coastal Southeast Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 10 (October, 1930), pp. 1301–13.

[8] Henry V. Howe, "Review of Tertiary Stratigraphy of Louisiana," *ibid.*, Vol. 17, No. 6 (June, 1933), pp. 648–54.

[9] F. B. Plummer, *op. cit.*, pp. 749–63, 776–95.

[10] Albert W. Weeks, "Lissie, Reynosa, and Upland Terrace Deposits of Coastal Plain of Texas between Brazos River and Rio Grande," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 5 (May, 1933), pp. 453–87.

[11] A. W. Weeks, *op. cit.*, pp. 464–66.

[12] F. B. Plummer, *op. cit.*, pp. 751–82.

Barton[13] suggested the inclusion of all of the formation south of the Hockley scarp in Harris County, Texas, in the Beaumont, and spoke of the formation lying above, or on the north side of the scarp as Lissie. In this paper the formation below the scarp has been placed in the Lissie, while that above the scarp has been found to be Willis. It is possible that local Beaumont deposits occur on the Lissie plain below the scarp, but the general physiographic feature is of Lissie age.

Howe,[14] in reviewing Louisiana stratigraphy, mentions the Beaumont, Port Hudson and Citronelle(?). The name Beaumont is correctly applied to the clay formation near Lake Charles. Howe does not give a definite correlation for the Port Hudson, but it has often been mentioned as the equivalent of the Beaumont. The locality has been of interest because it has furnished a collection of Pleistocene mammalian remains. These were found in the beds exposed in the bluffs overlooking the Mississippi River. The level of the fossil horizon in the bluff section is now unknown. At present the beds are better exposed in the Port Hickey bluffs, at the south. Here 40 or 50 feet of "Pinnacle beds" cap the bluffs, and are underlain by about 30 feet of blue clays which extend down to the water's edge. The "Pinnacle beds" are composed of sands, clayey sands, and sandy clays, and have a thin layer of gravel at their base. They are believed by the writer to show a section of the broad flat Lissie plain which extends eastward behind the river bluffs. It is possible, however, that they are a section of the narrow Beaumont plain which extends from Baton Rouge northward along the east side of the river valley toward this locality. The blue clays at the base of the bluff section are very possibly exposures of Fleming clay, since other clay exposures are found at the north as follows. The top elevation of the clays in the bluffs is about 50 feet above sea-level. Three miles north clay exposures occur in Sandy Bayou at elevations of about 60 feet. Three miles still farther north, in a bluff overlooking the west side of Thompson Creek Valley, is a large exposure of Fleming clays with top elevation of about 90 feet. Six miles northwest of this point, on roads just north of the town of St. Francisville, good exposures of Fleming clays overlain by Willis gravel, occur at elevations of 110 feet.

In his original descriptions of the Citronelle, Matson[15] included two types of deposit. One was the stratified formation near the coast

[13] Donald C. Barton, *op. cit.*, p. 1302.

[14] Henry V. Howe, *op. cit.*, pp. 648–53.

[15] G. C. Matson, "Pliocene Citronelle Formation of the Gulf Coastal Plain," *U. S. Geol. Survey Prof. Paper 98* (1916).

which the writer has called "Willis," and the other was a residual blanket of sand and gravel which covers large parts of the erosional plain inside the Willis cuesta. These residual deposits have been derived largely from the destruction of the interior extensions of the Willis formation, and therefore are post-Willis in age, possibly largely Lissie. They form an irregular blanket which follows the topographic surface and conceals the underlying formations. In southeast Texas and south Louisiana they occur over large parts of the Fleming outcrop, and in central Mississippi they cover a large area extending up to the outcrops of the Vicksburg and Jackson formations.

At the type locality, Citronelle, Alabama, the deposit occurs as a thick blanket on a Fleming area. The clay bed in which Matson found Pliocene plant fossils might have been part of the underlying Fleming, since the contact between the two is irregular, and, on account of the presence of sandy beds in the Fleming at this point, somewhat difficult to place definitely.

Since it would be convenient to have a name for this interior type of residual deposit, the writer suggests the restriction of the name "Citronelle" to this usage. This restricted use would still fit the type locality and the greater part of the "formation" which has been called by this name.

Plummer first mentioned the "unnamed Pliocene sand" formation of southeast Texas, which Weeks showed on his map as the "Lower Lissie," and which the writer describes more fully in this paper as the "Willis."

The geologists of the southwest Texas area separated a hard sandstone section from the lower part of Deussen's Reynosa and gave it the name "Goliad sandstone."[16] Weeks called the same section the "Upper Lagarto." The writer finds some exposures under the Willis beds in southeast Texas which might questionably be referred to the Goliad.

FLEMING FORMATION

The name "Fleming" is used in this paper as the general name for the clay formation overlying the Catahoula formation and underlying the group of formations that is being described. In southeast Texas and south Louisiana it is a predominantly clay formation, generally showing calcareous nodules, and containing some thin irregular sandstone sections. It equals the combined Pascagoula and Hattiesburg of the Louisiana and Mississippi section, and the combined Lagarto and Oakville of the southwest Texas section. The Oakville sandstone

[16] F. B. Plummer, *op. cit.*, pp. 750–60.

thins and disappears as a distinct surface member of the Fleming near the Brazos River in the southwestern part of the area here described.

In field work in this area the writer has found it convenient to place all of the clays found below the Willis formation in the Fleming. There is a distinct possibility, however, as discussed below under the Goliad, that some of these clay exposures may be related to the Goliad.

GOLIAD FORMATION

The only outcropping beds in this area which can be correlated with the Goliad formation of southwest Texas with any degree of certainty are the sandstones found on the Columbus-Eagle Lake highway south of Alleyton, in Colorado County, near the southwest edge of this area. Across the Colorado River, near Altair and Rock Island, similar sandstones have been described. Southward these sandstones can be found at intervals, increasing in thickness and strength of development until the type locality in Goliad County is reached. At Alleyton the sandstones are at elevations which place them at the base of the Willis. Southward a gravelly sand appears to be present above the upper member of the Goliad. This sand is believed by the writer to be a continuation of the lower Willis.

In southeast Texas some of the clay exposures found below the base of the Willis resemble the description of the clays of the Lagarto Creek member of the Goliad. They are brightly colored, some pink and some chalky white, and are streaked with red and purple. Some exposures appear to be slightly bentonitic. While they may simply be beds in the upper part of the Fleming, they are at least different in appearance from the typical green and gray, black-weathering Fleming clays found lower in the section. Maximum exposed thicknesses are about 15 feet. Greater unexposed thicknesses may be present. No contact or unconformity or abrupt change between these and the lower clays has been noted.

Exposure of these clays can be observed a few miles north of Magnolia, in the southwestern part of Montgomery County, in a deep gulley separating highway and railroad between the railroad signboards of Jackson and Mostyn (between mileposts 95 and 96, T. &. B. V. R.R.) These clays are separated from the overlying Willis ferruginous sand by only a few feet of the Willis gravel. Due west of Conroe in the same county, a smaller exposure of similar clays is found on the road between Honea and Keenan. Clays found cropping out on the Evergreen road a few miles north of Cleveland, also fit this description.

Gray sandstones found at a few points in southeast Texas have also been suggested as Goliad equivalents. Such outcrops occur on top of Davis Hill in Liberty County, and in the banks of the Neches River east of the Spurger field in Tyler County. The correlation is, of course, questionable.

It will be noted that these clays and sandstones are found in the coastward part of the Willis area, and represent the farthest down-dip exposures of the formations underlying the Willis. It therefore seems possible that they may be part of the feather-edge of an overlapped Pliocene section occurring between the Willis and Fleming, and correlating with the Goliad. The considerable thickness of Pliocene found in well sections near the coast requires that a rapidly thickening wedge of Pliocene appear in the subsurface section somewhere not far from these surface exposures. Wells drilled along the south edge of the Willis belt encounter pink gumbos and gravelly beds at shallow depths which are, however, too deep for the Willis. These may be part of the suggested overlapped Pliocene wedge.

WILLIS FORMATION

Name.—The name "Willis" is proposed by the writer for the formation of sand and gravelly sand occurring at, or near, the base of the post-Fleming group in southeast Texas and south Louisiana. The formation is named for the town of Willis, 10 miles north of Conroe, in Montgomery County, Texas. The town, as shown in Figure 1, is located on top of the north end of a ridge held up by the formation.

Character, areal extent, and stratigraphic position.—The Willis can be described in general as a red sand, coarse and gravelly in part, and slightly indurated. It is exposed in a dissected hilly belt 15 to 20 miles wide, paralleling and just south of the Fleming belt of outcrop. Its areal extent is shown roughly for the entire area in Figure 2. A more detailed view, for the area between the Trinity and Neches rivers, is given in Figure 6.

The Willis rests unconformably on clay beds which are, in part, Fleming, and which may be, in part, Goliad. It is covered and overlapped unconformably by the Lissie, and locally is overlapped unconformably by the Beaumont and Recent.

Subdivisions and thickness.—The Willis can be subdivided into three members, of which the lower two are exposed in the area around the town of Willis. The third and uppermost member is found at a few scattered points throughout the area. The members have the average maximum thicknesses here given in feet.

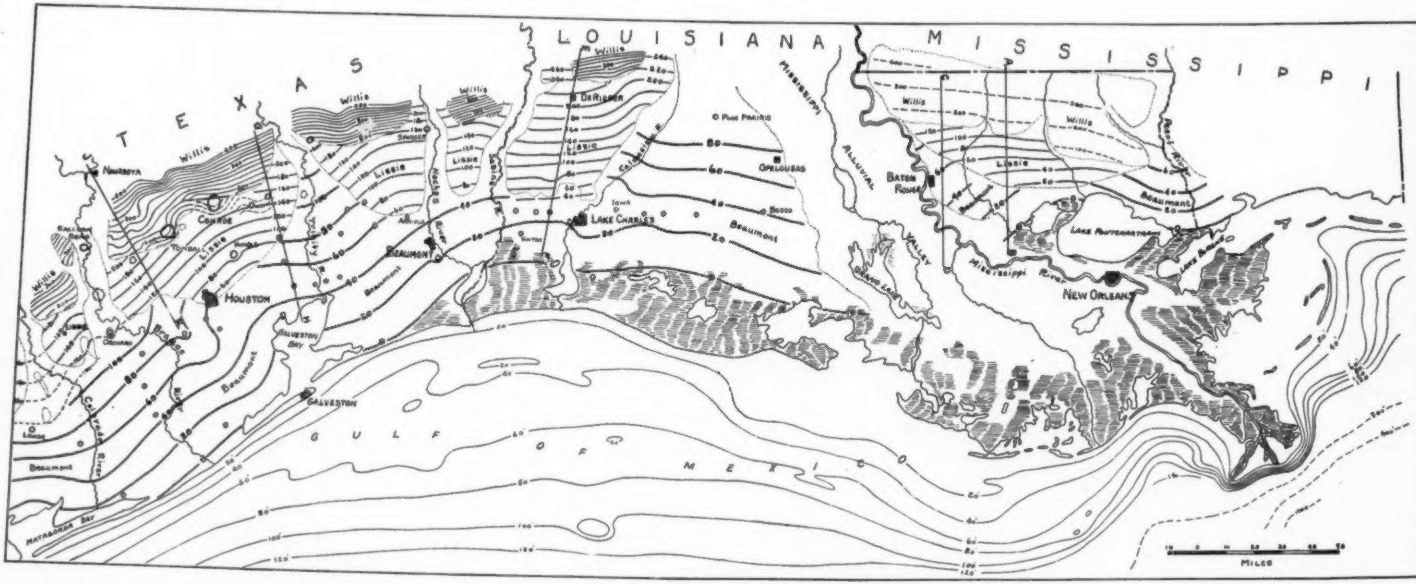

FIG. 2.—General surface structure of southeast Texas and south Louisiana. Contours on tops of Willis sand, Lissie, and Beaumont. Contour interval, 20 feet. Depth contours in Gulf of Mexico are in feet. Sections are shown in Figure 3

	Southeast Texas and Southwest Louisiana	*Southeast Louisiana*
Hockley Mound sand	20-25	20-25
Willis ferruginous sand	30	60
Willis gravelly sand	30	40

For convenience and brevity the two lower members have been referred to as the Willis sand and the Willis gravel.

Correlation and age.—The writer believes there is evidence to prove the correlation given by Plummer (Table I) correct. Near the Colorado River the lowest member of the Willis appears to rest on sandstone beds which resemble the Goliad. In the areas to the south in which the Goliad is recognized a gravelly sand section appears above the uppermost member of the Goliad, and at elevations which seem too high to permit correlation with the Lissie.

While the writer has not examined the area south of the Colorado River sufficiently to make a definite correlation, the relations observed make it seem highly probable that the Willis is younger than the Goliad. If there is an equivalence, it is only partial—that is, the upper member of the Goliad, the Labahia, may be the equivalent of the lowest member of the Willis, the Willis gravel.

No fossils have been noted in the Willis. Since Pliocene fossils have been found in the Goliad,[17] presumably indigenous and in place, and Pleistocene fossils in the Lissie, the correlation given in the preceding paragraphs would date the Willis as late Pliocene or early Pleistocene.

Willis gravelly sand member.—The Willis gravelly sand is the basal member of the Willis formation. It rests unconformably on clays which are part of the Fleming formation, or which locally may represent part of an overlapped equivalent of the Goliad formation. It is covered conformably by the Willis ferruginous sand.

The average thickness of this member in the parts of the area west of the Mississippi River is 30 feet. In southeast Louisiana it is 40 feet. The unconformable contact with the underlying clays has 10 feet or more of relief locally, causing undulations in the basal contact, and consequent local variations in thickness. At a few points the surface of the clays has sufficient relief to eliminate the gravelly member entirely. At such points the clays occur directly under the Willis ferruginous sand member.

This gravelly sand member is made up of about 5 per cent, or less, of gravel, 5 per cent of disseminated clay, and the remainder of sand. The sand is coarser than that of succeeding members and formations. Washed samples show an assortment of fine and coarse grains, with

[17] F. B. Plummer, *op. cit.*, p. 760.

many coarse, irregular-shaped and sub-angular quartz grains resembling the "rice sands" of the Catahoula formation. These coarse grains can be seen plainly in many of the exposures of the member. The sand is not cemented, but contains minor amounts of disseminated clay and bentonitic material which acts as binder. It is sufficiently consolidated and indurated to stand up well in road cuts, but can be easily broken out in chunks with the pick and crushed in the hands.

The gravel is mostly light-colored quartz and chert, but varying amounts of darker-colored pebbles are present. The gravel sizes vary up and down the dip, with sizes of an inch diameter on the up-dip side, and averages of about a quarter-inch in the farthest down-dip exposures. The important characteristic of this member is that it is a sand member peppered with scattered gravel, and not simply a gravel bed. Deposits reworked from it can generally be differentiated as concentrates of gravel, whereas the original exposure appears as a clean coarse sand, with gravel scattered through it at fairly uniform intervals. The amount of gravel present is greater toward the interior, and locally the concentration is greatest near the base of the member. Where the gravel is especially abundant it commonly occurs in small, flat, irregular lenses.

In mapping surface structure, the base of this member is taken at the contact with the underlying clays, and the top at the highest gravel occurrence. In places there is some lenticular bedding with thin partings of whitish or purplish clay at this upper contact, but ordinarily it can be recognized only by the absence of gravel in the overlying section.

The color of this member is reddish or pinkish, with sections of mottled red and white. The color is generally not as deep as that of the overlying ferruginous sand member.

Willis ferruginous sand member.—Overlying the Willis gravelly sand throughout this area is a red sand section of somewhat similar appearance, except that it contains none of the siliceous gravel which is characteristic of the lower member.

The sand of this member is somewhat finer and more evenly sorted than that of the gravelly member. Exposures have a reddish color, pale in fresh unweathered outcrops, and very deep or heavily mottled in weathered outcrops. Bedding is generally absent. Where present it is massive and irregular. Clay is present in varying amounts in different parts of the area. Generally the lower half of the member contains a greater amount of disseminated clay than the upper half. Beds of clay are encountered in a few places. They are merely local in

extent, dying out within the length of an exposure, and few are a foot thick. The section just above the base of the member can be recognized in some places by the presence of small streaks and scattered small flakes and balls of white bentonitic clay in the sand.

The average thickness of this member in southeast Louisiana is 60 feet, while in southwest Louisiana and southeast Texas it is 30 feet. Variations from these figures do not, as a rule, exceed 5 feet.

Besides the difference in thickness in the two parts of the area there is a difference in the amount of ferruginous material present in the member. In southeast Louisiana the Willis sand contains scarcely more iron than the Willis gravels, and is simply a massive, compacted red sand, in some places cross-bedded and irregularly mottled, in which no siliceous gravel is found. In southwest Louisiana and southeast Texas, the Willis sand is a highly ferruginous sand, containing an abundance of iron disseminated as cementing material, and occurring on its surface as weathered limonite deposits and nodules.

These ferruginous nodules covering the outcrop of this member are a characteristic feature west of the Mississippi. In many places where actual exposure of the member is difficult to find, due to soil cover or overlap of formations, its presence can be detected by an abundance of these nodules on the surface. They range in size from ¼ inch to 1 inch in diameter, and are brown to black in color. Some are concretions, while others are simply small rounded pieces of ferruginous sand. At many points, generally on hill- or ridge-tops, these nodules have accumulated to a depth of 2 or 3 feet, and are excavated for road metal.

This member is sufficiently cemented and protected by its iron deposits in the areas west of the Mississippi to make it a semi-resistant formation. It holds up long narrow ridges which generally extend up the dip to the northward-facing escarpment overlooking the Fleming area. Where it is present over large areas the top of this member is an important key bed in mapping surface structure.

In southeast Louisiana where the member is less ferruginous it is also less resistant, and is present in full thickness over only a small part of the Willis area, principally along the southern edge. On account of its lack of resistance the member is poorly exposed and its top in this part of the area does not make a very useful or reliable key bed.

Hockley Mound sand member.—The third and uppermost member of the Willis formation is called the Hockley Mound sand after a conspicuous small mound on the Willis plain about 4 miles southwest of Hockley, in Harris County, Texas.

This member is present in thicknesses up to 25 feet in a few small scattered patches. Over larger areas it is present as a thin sand cap only a few feet thick on the crests of the ridges held up by the ferruginous Willis sand member.

The sand of this member is light-colored, fine-grained, and so soft and easily eroded that only these small remnants of the member have escaped erosion. It is seldom seen in a fresh exposure, but is generally found as a weathered sandy soil on the divides above the exposures of the top of the Willis sand. In parts of the area the member contains some clay.

Best development of the member occurs near Hockley, Waller, and Tomball, in Harris County, near Woodville, in Tyler County, and along the south edge of the Willis area in southeast Mississippi.

Section *JK* of Figure 3 and the contours of Figure 5 give the relations in the Hockley Mound area. The elevation of the top of the mound is 245 feet, and that of the top of the Willis sand is 220 feet. This gives a local thickness of 25 feet. East of Waller several small areas show thicknesses of 20 feet.

Figure 7, which gives topography and surface structure in the Tomball area, shows elevations of 240 feet along the ridge 2 miles west of the town and in the north part of the field. The top of the Willis sand is indicated by the structural contours to be about 220 feet or less in elevation, giving a thickness of 20–25 feet for the member.

On Figure 6 a small area assigned to the Hockley Mound is indicated about 2 miles southwest of Woodville, Tyler County. The ridge tops are here 20 feet higher than the exposures of the top of the ferruginous Willis sand.

In sections *AB* and *CD* of Figure 3 the occurrence of the Hockley Mound member in southeast Louisiana is indicated. At a few points it is found capping the hills and ridges of Willis sand in the interior part of the Willis area. It is more common along the south edge of the Willis, where it is found in thicknesses of 20–25 feet above the exposures of the Willis sand.

Sections of Willis.—The town of Willis is located on the north end of a ridge which plunges southward to the town of Conroe. Figure 4 gives a sectional profile along the Houston-Dallas highway which runs along the east edge of this ridge in passing through Conroe and Willis. Good exposures of the Willis are found in roadside cuts along this highway. In crossing local hilltops the highway is on the ferruginous Willis sand, while in crossing the local drains it drops down into the Willis gravelly sand member.

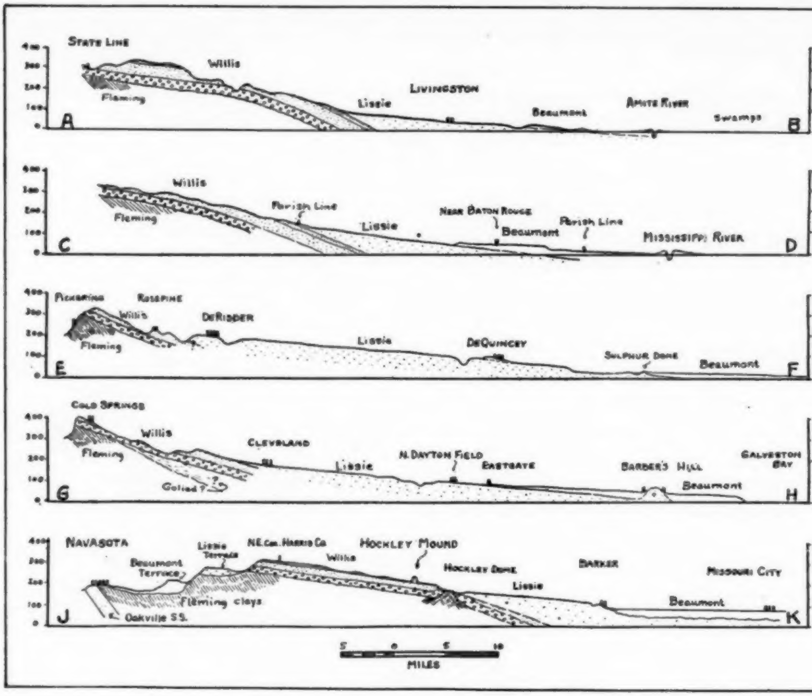

FIG. 3.—Sectional profiles of post-Fleming formations. Location of sections shown in Figure 2.

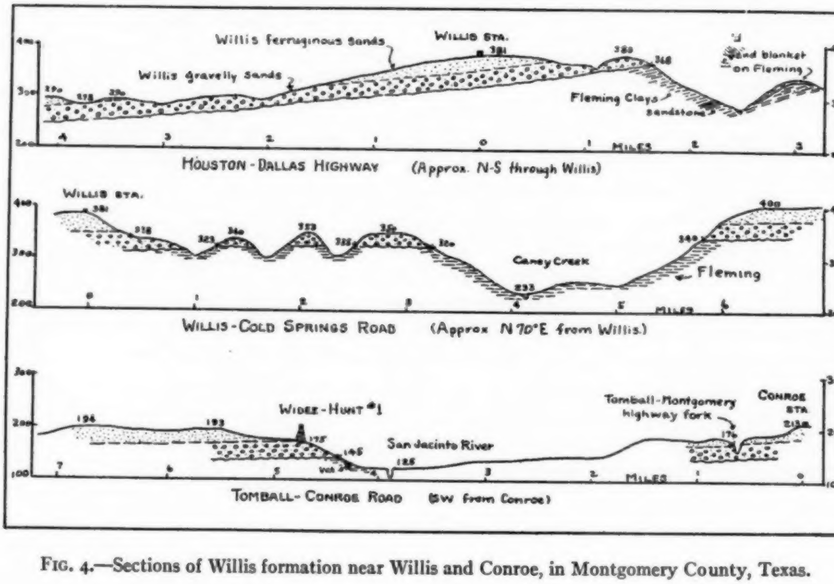

FIG. 4.—Sections of Willis formation near Willis and Conroe, in Montgomery County, Texas.

The ground surface in the town of Willis is the top of the Willis sand member. A good section of the upper part of this member is shown in the railroad cut just south of the Willis station. It is heavily mottled and limonite stained, showing the effect of weathering on this member.

About a half mile north of the town of Willis the Dallas highway drops down into the Willis gravels, and a mile farther north it drops down off the Willis escarpment into the Fleming clays. A good exposure of the lower part of the gravel member and its contact with the underlying Fleming clays occurs at this point. This is the most northerly exposure of the Willis along this highway. The sands seen along the road to the north are part of the residual sand blanket which is found over much of the Fleming area.

The second sectional profile in Figure 4 shows the topography and exposures along the first 7 miles of the Willis-Cold Springs road. The course of the road is approximately along the strike of the formation. Three good contacts of the Willis on the Fleming are shown, as well as several good sections of the Willis sand and the Willis gravel. The base of the gravel member is found at about 320 feet elevation, the top of the gravels at about 350 feet, while the top of the Willis sand member in the town of Willis is at about 380 feet. The figures on the section indicate the manner in which small local variations are found in the thicknesses of the member, while a fairly uniform average is maintained over large areas.

The third sectional profile in Figure 4 gives the topography and exposures along the Conroe-Tomball road, which runs approximately southwest from the town of Conroe. About a mile west of the Conroe station, at the fork of the Montgomery and Tomball roads, sections of the Willis sand are exposed in the highway and railroad cuts. Immediately to the north of the highway at this point, in the sides of a gully, the gravelly sands of the basal member of the Willis are exposed. The sands in this exposure contain an abundance of coarse grains.

About 4 miles farther southwest on the Tomball road, the section crosses the San Jacinto River and rises up a hill past the location at which the Widee-Hunt Lumber Company well was drilled.

The pit for a cattle-dipping vat at the base of this hill was dug in the clays below the Willis. A short distance up the hill from the vat the basal contact of the Willis on the underlying clays is exposed in the ditches at the sides of the road. Above it is a continuous exposure of 30 feet of pink gravelly sands. The top of the gravel member is opposite the site of the test well. South of this point the road con-

tinues up to the top of the ridge through a weathered and poorly exposed section of the Willis ferruginous sand. The soil covering on this upper section consists of a mixture of sand and small ferruginous nodules.

In Jasper County, Texas, good exposures of the Willis are found near Erin, about 12 miles northwest of Kirbyville on the old Kirbyville-Jasper highway. Just southeast of the Erin road corner is a good exposure of unweathered Willis sand in a long roadside cut. In the 4 miles north of Erin along this highway a series of exposures of the top contact of the Willis gravel can be found.

The Willis section in southwest Louisiana can be seen on the DeRidder-Leesville highway between Neame and Pickering, in the southern part of Vernon Parish. Neame is on the ferruginous Willis sand. Immediately north the rough topography which is part of the Willis escarpment shows excellent sections of both the ferruginous and gravelly members of the Willis. Pickering station is below the escarpment in the Fleming clays. The contact of Willis on Fleming is marked at this point by a 2- or 3-foot bed of case-hardened white clayey sand.

In southeast Louisiana good exposures of the Willis can be found around Clinton, East Feliciana Parish. The gravels are exposed at low elevations in the town, while the high hills several miles east of town on the Greensburg highway expose sections of the 60-foot Willis sand member. Farther east on the Clinton-Greensburg highway the 5 or 6 miles west of the Amite River shows numerous good exposures of the Willis gravel, while the highway between the Amite River and Greensburg shows almost continuous exposures of the Willis sand.

LISSIE FORMATION

The Lissie is the middle formation of the post-Fleming group. It is the surface formation in a belt of flat plains about 25 miles wide, partly prairie and partly wooded, extending along the coastal side of the Willis hilly belt. The main body of the Lissie rests on the top of the Willis, but smaller tongues extend up into the interior through the stream gaps cut in the Willis cuesta, crossing the Willis and Fleming unconformably. Farther up in the interior these Lissie terraces possibly merge with an old erosional surface marked by such deposits as the Uvalde gravels of south Texas. On its coastward side the Lissie is overlain by the Beaumont formation, which also extends tongues up into the stream gaps, crossing Lissie, Willis, and Fleming unconformably.

The slope of the top surface of the Lissie is about 5 feet per mile,

while that of its base, which is the top of the Willis, averages about 20 feet per mile. This discordance in rate of dip gives the Lissie a coastward thickening of about 15 feet per mile, from which a thickness estimate of about 1,000 feet at the present coast line can be derived. Since the rate of dip of the Willis may be greater nearer the coast, this estimate should be regarded as a minimum. The thickness of the Lissie terrace deposits in the stream gaps probably averages 20–50 feet.

The sands of the Lissie are finer than those of the Willis and contain a considerable amount of disseminated clay. They can be described as fine light-colored sands, clayey sands, and sandy clays. Since the Lissie is in general not sharply dissected, our principal view of the formation is of its weathered surface. This is covered by a set of fine buff and gray sandy-loam soils. An excellent picture of the Lissie soils is given by the United States Department of Agriculture Soil Map of Beauregard Parish, Louisiana, since the greater part of this parish is covered by the Lissie. Harris County, Texas, is another area in which a study of Lissie soils is available. There, however, the limits of the Lissie and Beaumont formations are not so readily determined as in Beauregard Parish. Barton,[18] in his discussion of the Harris County soils, finds some Beaumont soils on the plain which is placed by the writer in the Lissie.

Some of the Lissie areas near the Colorado River are notable for the coarseness of their sands. Such areas occur near El Campo, in Wharton County, and farther north, near Taiton. These sand patches are surrounded by the black clays of the Beaumont, but are believed to be Lissie inliers.

Near the edges of the Lissie areas, where the topographic relief is greatest, sections of the Lissie can be seen along the roads. These generally show a sandy section at the top grading down into clayey sands and then into sandy clays. The sandy clays are in places reddish and in places gray, and usually occur 20 to 30 feet below the top of the formation. On account of their depth in the section and the low topographic relief of the formation, they are not ordinarily exposed at the surface. It is questionable whether there is any great regularity in these sections or whether they could be correlated.

In the Lissie areas near the Sabine River, in Hardin, Jasper, and Newton counties, Texas, and Beauregard Parish, Louisiana, the sand at the top of the Lissie has a slightly ferruginous character. Its weathered exposures in road cuts show accumulations of limonite nodules which are somewhat more brownish in color and more clayey than those found on the surface of the Willis sand. This local ferruginous

[18] Donald C. Barton, *op. cit.*

character is possibly due to deposition of this part of the Lissie by streams heading in the ferruginous Claiborne areas of east Texas and west Louisiana.

Sections showing this character of the Lissie can be observed near Silsbee, in Hardin County, and Buna, in Jasper County, Texas. Just east of Silsbee, on the Kirbyville highway, the descent from the Lissie plain in the town down to the Neches River bottoms shows a Lissie section grading from limonite-mottled pinkish sands at the top down through clayey sands to sandy gray clays at the base. The ferruginous nodules can be noted on the roads northwest of Silsbee and the roads east of Buna. A particularly good exposure is found on the old Kirbyville highway about 4 miles northwest of Buna. It shows a 25-foot section grading from ferruginous clayey sands at the top down to sandy clays. In these sections it is to be noted that the sands have a clayey appearance, and that the covering soils are loamy. This is in contrast to the Willis areas, which show coarse loose sandy soils.

In naming the formation, Deussen first called it the "Lissie gravel." This was probably due to the inclusion of part of the Willis gravelly sands in his original Lissie. More recently the formation has generally been referred to as the "Lissie sand." In this examination gravel was noted in the formation in only a few restricted localities. These were generally located at points where the Lissie crosses or covers the basal Willis gravel unconformably, the gravel derived from the underlying formation being concentrated locally in such cases in the Lissie. The gravel pits found at intervals along the Lissie-Willis contact are at such points, generally in the stream gaps through the Willis cuesta. Farther downstream the gravel disappears from the surface Lissie, or is too deep in the section to be exposed. Since the Lissie is derived in part from the destruction of Lower Willis in the interior, it seems that a greater amount of gravel should be found in the Lissie than is noted. The explanation is possibly that a large part of the gravel was left in the interior in deposits of the Uvalde and Citronelle type.

Only a few exposures of gravelly sand were found in the main body of the Lissie along the coast. Although these are probably a part of the Lissie, they could be considered possible occurrences of the Lower Willis, uplifted, and truncated and overlapped by the Lissie. These exposures were found at Lissie, in Wharton County, Texas, and near Fields and Dry Creek, in Beauregard Parish, Louisiana.

At Lissie, Texas, the type locality, Deussen reported a fossil-bearing gravelly sand at a depth of 25 feet in a dug well. This point is located on the south flank of what is believed to be a Willis surface

structure, truncated and overlapped by a thin deposit of Lissie, which corresponds to a geophysically discovered subsurface structure lying between Eagle Lake and Chesterville. The gravelly sand in the well would fit into the surface structure as an occurrence of the Lower Willis. However, the presence of Pleistocene fossils in the well seems to place the exposure in the Lissie.

A 60-foot section exposed on the Merryville road about 4 miles northwest of Fields shows ferruginous clayey sands at the top, coarser gravelly sands in the middle, and gray sandy clays at the base. In the Dry Creek area a small amount of gravel was found in several low exposures, one just south of the Dry Creek-Reeves highway crossing of Dry Creek, and others to the west on local road crossings of the same creek.

Although geophysical structures were found in the Fields and Dry Creek areas, the surface uplifts required to bring the Willis gravel to the surface would be much greater than seems to be common for the Willis disturbances. It seems more probable that these sections are part of the Lissie, probably a lower part than is commonly exposed. The combination of sharp relief and some surface uplift possibly accounts for their outcrop in these local areas.

BEAUMONT FORMATION

The Beaumont is the most extensive of the post-Fleming formations. It covers about half of the total area occupied by the group, extending, in Texas, from the Lissie areas to the present coast line, and, in Louisiana, from the Lissie areas to the edges of the marshes along the coast. It forms large flat plains which have even less relief than the Lissie plains. Stream erosion and gulleying have scarcely touched large parts of the Beaumont. It is partly prairie and partly wooded.

In addition to the broad areas near the coast, the Beaumont extends up into the stream gaps trenched through the Willis and Lissie, and forms terraces on the sides of the present river valleys. The Colorado, Brazos, Trinity, Neches, Sabine, Mississippi, and Pearl rivers have cut trenches down into the Beaumont in these stream gaps. Of these only the Mississippi trench is of important size. It is 30–40 miles wide, and is occupied by the present alluvial valley of the Mississippi River.

In the areas between streams, the Beaumont overlaps on the Lissie surface, due to their differing rates of slope. The Beaumont rate of slope is about 2 feet per mile while that of the Lissie is about 5 feet, giving a rate of thickening of about 3 feet per mile. The thickness

of the Beaumont therefore ranges from a feather-edge along the Lissie-Beaumont contact, and from 20 to 50 feet in the interior terrace deposits, to a minimum of about 100 feet along the present Texas coast line. If the slope of the Lissie increases near the coast the Beaumont will have a thickness along the coast correspondingly greater.

In the stream gaps the Beaumont terraces overlap the Lissie, Willis, and Fleming unconformably. They probably continue farther up into the interior, crossing the older formations and possibly merging with deposits of the Leona type.[19]

The Beaumont is generally described as a clay formation, but it contains also much sandy material. An inclusive description would list clays, limy clays, sandy clays, clayey sands, and fine sands. The lime is present in small and large nodules, in shell beds, and disseminated through the clays. The distribution of the sandy areas has been shown by Barton[20] to be related to the system of distributary ridges by means of which the formation was deposited. The coarser materials are on, or near, the ridges, while the finer materials are at a distance, or between the ridges. The calcareous sediments were probably deposited in coastal marshes which extended up between the distributary ridges as do those on the present Mississippi delta. Some large sandy areas occur in the Beaumont. The north half of Orange County, Texas, is a sandy Beaumont plain, while the southern part is covered by the typical heavy black soils weathered from the clay phase of the formation.

East of Lake Charles, on the large Beaumont plain deposited by the Mississippi and Red rivers, there are some large clay areas near the coastal marshes, but much of the area in the interior is sandy. A large distributary ridge can be traced in this area, coming down the east side of Calcasieu River toward Lake Charles.

The Beaumont area near Baton Rouge is covered mostly by sandy loam, but there are local areas in which clays and sandy clays containing heavy deposits of large calcareous nodules occur. The Beaumont fan at the mouth of the Pearl River shows no calcareous material, and not much clay. It is made up chiefly of sands and clayey sands. It may be in part a Lissie deposit, though it seems to have too low a slope to be Lissie.

Loess deposit in southeast Louisiana.—In southeast Louisiana a large loess deposit is found lying along the east side of the Mississippi River valley. It covers the bluffs and upland in a belt 15 or 20 miles

[19] F. B. Plummer, *op. cit.*, pp. 795–97.

[20] Donald Barton, *op. cit.*, pp. 1303–09.

wide which extends as far south as St. Francisville. This is a southward continuation of a similar loess deposit which is found along the east side of the Mississippi Valley northward across Mississippi, Tennessee, Kentucky, and Illinois.

This loess is a wind-blown deposit formed during the glacial period by air currents lifting fine powdery material from the river flats and dropping it in the quieter air behind the river bluffs.

In this area the deposit is possibly 50 feet thick in a few spots along the river bluffs. It thins away gradually and disappears at a distance from the river, forming an irregular mantle on the surface and concealing the underlying formations. Near the river the local relief is so great that exposures of the Willis and Fleming contacts can be found in the banks of the gulleys cut down through the loess. Enough such points can be found to give the picture of the surface structure.

The loess lies on a considerably eroded Fleming and Willis surface north of St. Francisville. This seems to indicate its deposition considerably later than those formations. A small area of loess south of St. Francisville seems to lie on the Lissie, while farther south no loess has been noted in the Beaumont areas. These relations seem to indicate that the deep erosion of the Willis occurred while the Lissie was being deposited, and that the loess deposition occurred later, during the Beaumont. This loess deposit should possibly be correlated with the Iowan (?) loess which is the principal loess deposit of the interior glaciated areas.

THE RECENT

The Recent in this area consists principally of the alluvial deposits and low post-Beaumont terraces in the valleys of the present streams, and the delta and beach and marsh deposits being built along the present coast line.

Except in the case of the Mississippi River valley and delta, these deposits do not cover very large areas. The Mississippi deposits are chiefly of interest because they are on such a large scale as to illustrate the ability of rivers to produce these coastal plain formations.

From the point of view of mapping surface structure the Recent deposits appear to be hopeless. The writer has noted no surface anomalies which could be separated from these young depositional surfaces. The underlying subsurface structures have possibly not moved sufficiently in Recent time to produce recognizable anomalies, or the changes in the surface have removed or obscured them.

ORIGIN AND HISTORY OF FORMATIONS

DEPOSITIONAL CYCLES

The formations of this post-Fleming area record a series of depositional cycles which constitute the latest chapter in the history of the Gulf Coast geosyncline.[21] The gradual change in the texture of the formations, from a coarse basal deposit to the fine silty deposits of the present time, shows a slow change from early conditions favoring strong erosion and deposition to the milder conditions of the present.

The factor responsible for the division of the record into cycles was probably repeated gentle flexing of the coastal area. Lightening of the interior continental block and weighting of the geosynclinal block along the coast by transfer of sediments from one to the other has caused a rising of the interior and a settling along the coast, resulting in a flexing of the sedimentary formations which cross from one block to the other. The post-Fleming formations of this area lie along the coastal limb of these flexures and record the movements as gentle coastward tiltings.

The necessity for such a theory of flexing is apparent when it is considered that the Pleistocene Beaumont and Lissie formations at the mouth of the Mississippi River, with present slopes of 2 and 5 feet per mile, respectively, were at one time continuous with the Pleistocene deposits of the Upper Mississippi Valley. In central Illinois, more than 400 miles in the interior, these now have maximum elevations of about 800 feet above sea-level, and there is evidence to show that they are now higher, rather than lower, than they were when the interior was weighted down by the Pleistocene ice sheets. Normal stream profiles from these deposits to the mouth of the Mississippi River of Pleistocene times would have produced depositional profiles along the coast of about one foot per mile. By comparison, the present Mississippi Valley, with an elevation of 320 feet at the mouth of the Ohio River—at the southern tip of Illinois—has a slope of about 6 inches per mile over its lower 100 miles. The 2- and 5-foot Beaumont and Lissie profiles of the present time must have been produced partly by tilting.

Barton[22] has described a depositional history for the Beaumont of the Brazos and Trinity river areas in southeast Texas which resembles the deposition on the present Mississippi River delta, and

[21] Donald Barton, C. H. Ritz, and Maude Hickey, "Gulf Coast Geosyncline," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 12 (December, 1933), pp. 1446–58.

[22] D. C. Barton, "Surface Geology of Coastal Southeast Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 10 (October, 1930), pp. 1301–20.

has compared the distributary ridges found on the Beaumont with those found at the mouth of the Mississippi. The resemblance of the products of the two cycles suggests that the stream slopes during the Beaumont were very similar to those of the present time.

In the Lissie and Willis areas no evidences of the presence of distributary ridges has been noted. It seems, therefore, that the stream profiles and the depositional slopes might have been greater than at present. That is, the deposition might have been by means of shallow braided streams with constantly shifting channels, rather than by streams with deep channels which simply overflowed in flood seasons, as during the present time, and apparently during the Beaumont. The greater coarseness of sediment handled during Willis and Lissie time, as compared with the Beaumont and Recent, also suggest stronger stream profiles during the earlier cycles. The profiles to be observed on the Willis and Lissie at the present time seem, however, to be too great to be the original profiles, and are believed to be largely due to tilting subsequent to deposition.

SEQUENCE OF GEOLOGICAL EVENTS

Assuming the correlation of the Willis as younger than the Goliad to be correct, the writer has interpreted the sequence of events as follows. After the deposition of the Fleming and before the deposition of the Willis the coast was tilted about 25 feet per mile. During this interval a comparatively flat erosional plain was developed on the Fleming extending back to cuestas of the first hard formations, the Catahoula and Oakville sandstones. The stripping of the thick Fleming clay from this interior area in east Texas and Louisiana probably provided material for much of the thick Pliocene clay section found in wells near the coast.

The strong development of the Oakville sandstone in the Fleming of southwest Texas provided that area with a source for sandy material, during the latter part of this cycle, that was missing in east Texas and Louisiana. This abundance of sandy sediment plus the supply of limy cementing material from the great areas of Cretaceous limestones in the south Texas interior possibly explains the deposition of the Goliad sandstones in southwest Texas while only the possible clay equivalents were being deposited in the areas on the northeast.

A small additional movement at this time might have started the Willis cycle, causing erosion to attack the Catahoula formation vigorously and strip it from the interior. Through stream gaps in the Catahoula cuesta the Willis was discharged on the erosional plain developed on the Fleming and the interior edge of the Goliad. The

Catahoula probably contributed a considerable part of the coarse sand and possibly most of the quartz gravel found in the basal member of the Willis. Later, during the deposition of the ferruginous member of the Willis, the sands possibly came from areas farther in the interior and were more evenly sorted and finer grained. The very ferruginous Claiborne formations of east Texas and west Louisiana probably contributed most of the iron found in this member.

The gaps through which the Willis was discharged and the interior extensions of the formation have now been destroyed by erosion, and the Willis now found at the surface is part of the Willis plain developed at a distance from the gaps.

The streams which built the Willis were the ancestors of the present rivers of the coast. At this time they were developing their respective drainage systems in the interior. During succeeding cycles they retained the same interior drainage systems, simply depositing each succeeding formation farther south.

Following its deposition the Willis was probably tilted 10 or 15 feet per mile toward the coast, and deformed locally by uplift of local Willis surface structures. This flexing of the Willis rejuvenated the streams of the coast, first in their lower courses and later in the interior. The first action of the streams was to cut trenches down into the Willis plain. Destruction of the interior parts of the Willis plain during subsequent erosion has given these trenches their present appearance of stream gaps through the Willis cuesta.

When the rejuvenating influence of the post-Willis movement reached the interior erosional areas a new flood of sediments was brought down to the coast to form the Lissie formation. It was first deposited in the lower ends of the trenches cut in the Willis plain. When these valleys were filled, the deposit spread out sideward on the surface of the Willis to form fan-shaped deposits. These fans eventually grew until they reached from one stream gap to the next, forming a continuous plain along the coastward side of the Willis. Later tilting has reduced the apparent curvature of the surfaces of the fans, but it is still discernible.

The sediments brought down by the streams during the Lissie cycle were finer than those of the Willis. Coarse material was derived by the streams in crossing or side-cutting the Willis of the stream gaps. This was deposited locally in the Lissie to form the coarse gravel deposits found at intervals along the Lissie-Willis contact.

A new and smaller flexing movement probably brought the Lissie cycle to a close. Some of the deep-seated salt structures under the new Lissie probably moved at this time to make adjustment for the

new weight of sediment, producing local uplifts in the Lissie surface. The again rejuvenated streams cut trenches down into the Lissie plain, and presently began to bring down a new load of sediment which was deposited along the coast to form the Beaumont formation. This formation grew as did the Lissie by the spreading of the sediments sideward over the Lissie to form fans and eventually a continuous plain. The sediments in this formation were finer than those in the Lissie, a large proportion being clay.

The Beaumont cycle was ended by a new movement which permitted the streams to cut their present valleys down into the Beaumont. Since that time the Colorado and Brazos rivers seem to have been more active in filling up the lower parts of their valleys than have the Trinity, Neches, and Sabine. The Mississippi has built a recent delta of considerable size, and recently has moved forward to start a new extension of its delta.

A study of depths offshore in the Gulf of Mexico shows that the bottom south of Lake Charles has approximately the slope of the Beaumont deposits. This makes it seem probable that the continental shelf was built up almost to its present shape during the Beaumont cycle, and that the recent delta of the Mississippi has simply been built out on a portion of a large submerged Beaumont delta. Additional evidence of this seems to be given by the fact that if the Beaumont contours near Baton Rouge in Figure 4 are projected southward they will pass under New Orleans at a depth of 40 or 50 feet below sea-level, at which depth a change in sediment from the Recent to an older series is reported.[23] The crooked course of the Mississippi above New Orleans is cut down into a Beaumont base, while south of the city the chutes are in the easily cut Recent sediments.

STRUCTURE

The general surface structure of the area is given in Figure 2. Contours are shown on the tops of the Willis sand, the Lissie, and Beaumont. For each formation they show a low continuous dip toward the coast, 20 feet per mile for the Willis, 5 feet for the Lissie, and 2 feet for the Beaumont. These differing rates of dip might be explained as due to differing primary dips, but they are interpreted by the writer, as already discussed under Geological History, as due to tilting movements which occurred between the several cycles of deposition.

The regularity of the structural contours is interrupted at intervals

[23] A. C. Trowbridge, "Building of Mississippi Delta," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 7 (July, 1930), pp. 874–76.

by small noses and bulges. These are the surface prospects which have been interpreted by the writer as indications of underlying subsurface structures. In the Willis areas these local disturbances are of comparatively large size, and in some cases show as much as 50 feet of uplift of the surface formation. In the Lissie and Beaumont they are smaller in area, and generally show no more than 10 or 20 feet of uplift. In the Beaumont they are in many places restricted sharply to areas immediately overlying salt domes, forming in such places the conspicuous mounds found on the coastal prairies.

In another geological province these small and weak surface structures, with no closure and only 10–50 feet of uplift, would possibly have no value, but in this salt dome province they seem to be good indicators of subsurface structures which may have hundreds or thousands of feet of uplift and closure. A salt uplift once started may continue to rise through succeeding periods of time, eventually accumulating considerable relief, as one formation after another is deposited over it. The 10-foot surface uplift simply indicates a point where many earlier movements may have taken place.

WILLIS SURFACE STRUCTURE

Key beds.—In the Willis formation three mappable key beds are present. The lowest is the contact of the Willis gravelly sands on the underlying clays. The middle key bed is at the top of the gravel member, and the upper key bed is at the top of the Willis sand member. The interval between the lower pair of key beds is 30 feet in the Willis areas west of the Mississippi River and 40 feet in southeast Louisiana. The interval between the upper pair is 30 feet west of the Mississippi and 60 feet in southeast Louisiana.

Mapping of Willis structure.—The Willis is well dissected by many small streams, which generally flow down the dip of the formation. Between the valleys of these streams are long narrow ridges which in some places have sufficient relief to show exposures of all three key beds, one above another. The problem of mapping the structure of the Willis becomes simply a matter of running profiles on all the roads, and picking up the exposures of the key beds as they are encountered. They are of such a type that their best exposures occur in the gulleys and graded cuts at the sides of the roads. The relief of the surface structure is so gentle that continuous tracing of the key beds is not necessary. The intermittent scattered exposures in the road cuts give satisfactory control. Though the exposures of the key beds are not difficult to find, not all of them are conspicuous, and in places it is necessary to run preliminary surveys of the good

exposures to determine where to hunt closely for additional outcrops.

Where there is disagreement between the structure shown by the upper two key beds and that by the basal contact with the Fleming clays, the structure of the upper beds should be considered the better, since the top of the Fleming is an erosional surface which occasionally has considerable relief. It should be noted that structure mapped on the top of the Fleming is post-Willis structure, the same as that mapped on the members of the Willis.

In Figures 2, 5, 6, and 7, the contours on the Willis are drawn on the top of the Willis sand member. In the Willis area in southeast Louisiana the data are not complete and the dashed hundred foot contours are intended simply to give the general strike and dip of the formation in that area.

Tomball surface structure.—The only definite Willis structure which has been proved to date by discovery under it of an oil field is that at Tomball, in Harris County, Texas. Pictures of surface structure similar to that shown in Figure 7 were mapped in this area by several geologists prior to the drilling of the geophysical prospect.

This figure illustrates the manner in which only a few scattered points on the key beds serve to give the normal structure, while the few abnormal points require the presence of a surface anomaly. The points given are the good exposures found along the roads. A search off the roads might have given additional points for filling in the detail of the anomaly.

The gravel exposure on the road just south of Spring Creek in the northwest part of the field, is probably close to the top of the Willis gravel. The exposure of the Willis sand (elevation, 220 feet) in the west edge of the field is a long roadside cut which shows most of the member, but does not go low enough to expose the gravel member. Bored water wells drilled just west of this exposure and starting at the level of its top, were reported to have passed through 30 feet of red sand before finding water in a gravelly sand. Since the development of the field many additional points on the surface beds have probably been exposed.

The topography north of Spring Creek has been sketched by connecting road profiles, and is not accurate. That south of the creek is from the Harris County sheets by the United States Geological Survey, which are contoured with a one-foot interval. Over most of the area it can be observed that the high points of topography are approximately at the level of the top of the Willis sand. Along the ridge in the north part of the field, elevations reach 240 feet, and seem to be 20–25 feet above the top of the Willis sand. These local high points

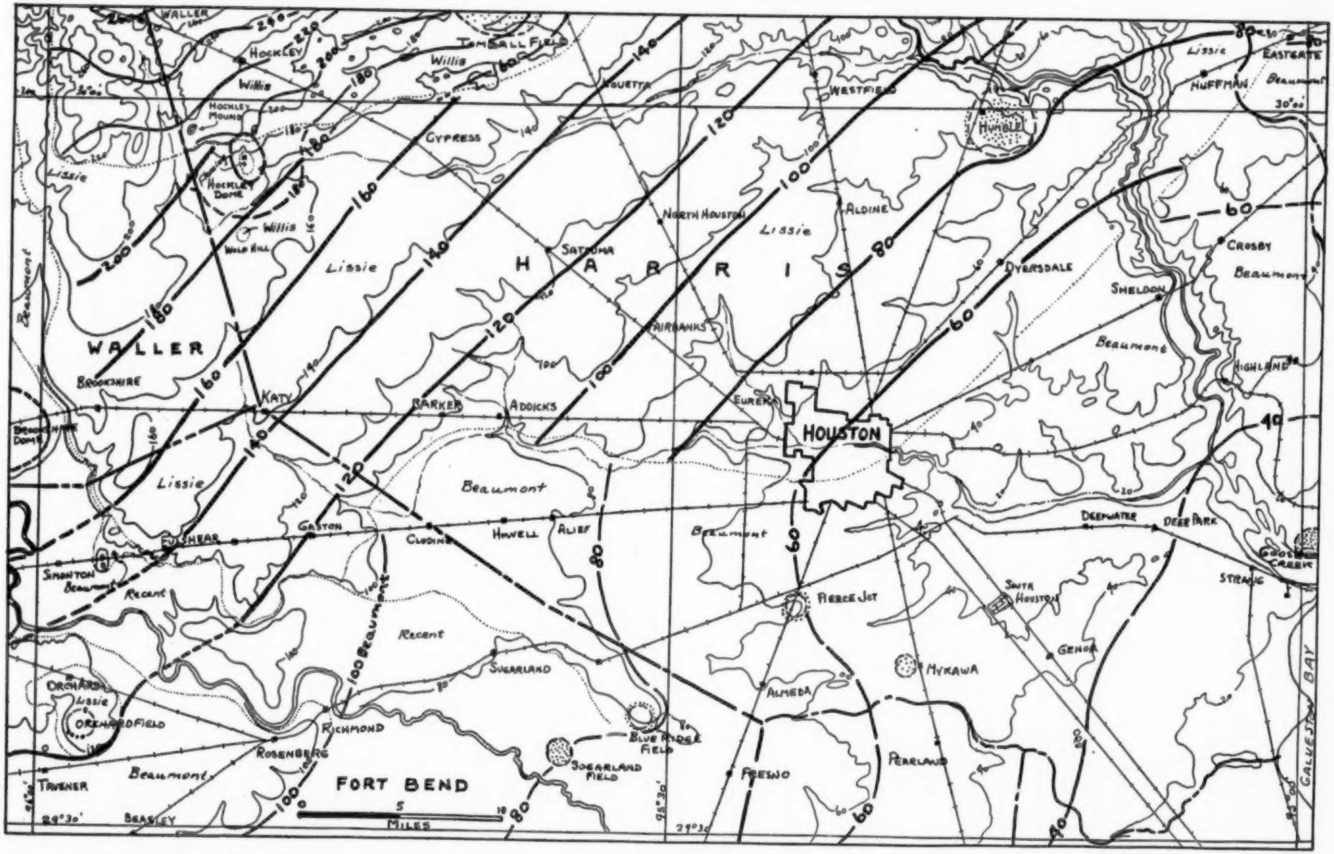

FIG. 5.—Houston area, southeast Texas. Structural contours on tops of Willis sand, Lissie, and Beaumont. Contour interval structure and topography, 20 feet.

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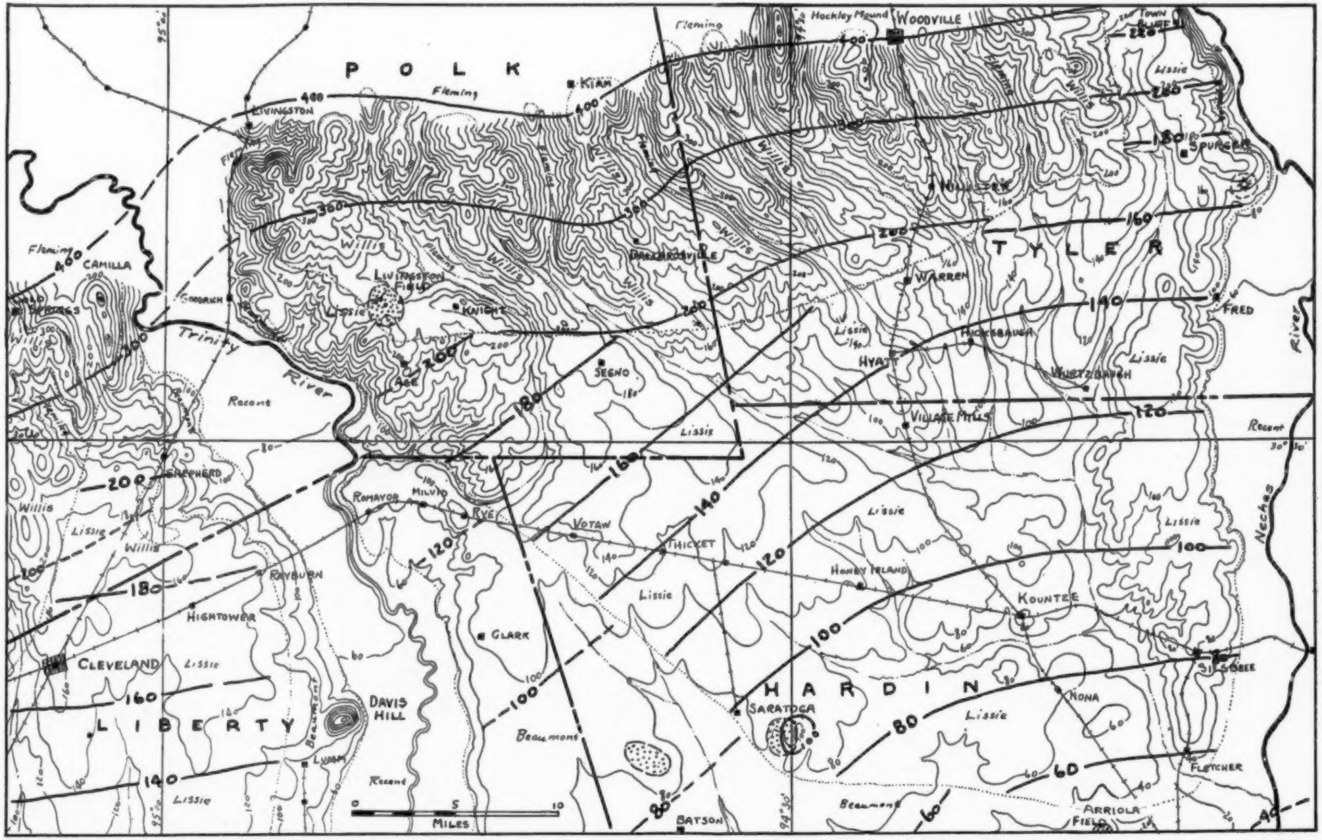

FIG. 6.—Cleveland-Woodville area, southeast Texas. Structural contours on tops of Willis sand, Lissie, and Beaumont. Contour intervals: Willis structure, 100 feet· Lissie and Beaumont structure, and topography, 20 feet.

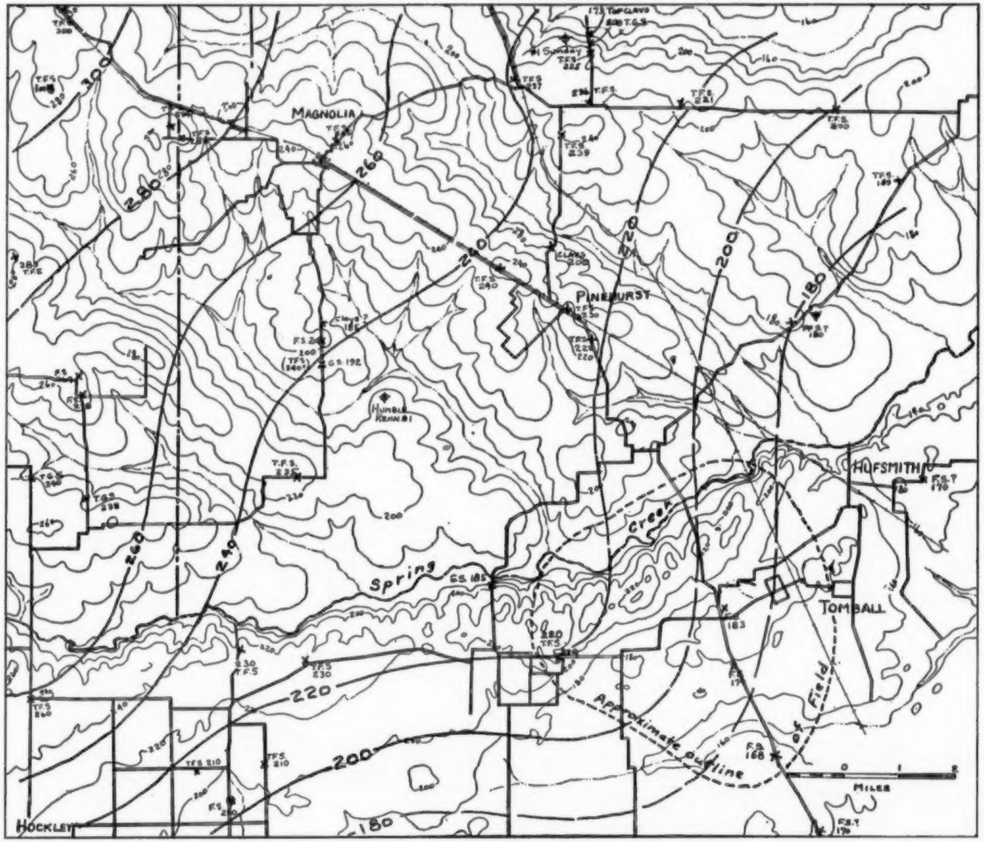

FIG. 7.—Tomball area, Harris County, Texas. Structural contours on top of Willis sand. Contour intervals: structure and topography, 20 feet. *T.F.S.*, top of Willis ferruginous sand member. *T.G.S.*, top of Willis gravelly sand member. Topography south of Spring Creek from Harris County topographic sheets; north of Spring Creek, sketched from road profiles.

are believed to be remnants of the Hockley Mound member. If they are part of the Willis sand, they show a much stronger surface anomaly than that given in the figure.

The clay exposures at elevations of 200 feet near Pinehurst illustrate the irregularity in the top of the clays underlying the Willis. The elevation of the top of the Willis sand at this point is about 230 feet. No gravel is noted above the clays, so that it seems probable that the irregularity in the top of the clays has locally eliminated the Willis gravel.

Conroe and Cleveland structures.—Questionable surface structures have been mapped in the areas of the Conroe and Splendora-Cleveland fields. These are indicated by the dashed contours in Figure 2.

LISSIE SURFACE STRUCTURE

The only datum surface which can be recognized throughout the Lissie areas is the top or depositional surface of the formation. In the field, and on soil maps, it can be seen that between the shallow drainages there are broad flat divides which have been untouched by erosion. In many places these are so flat that they are poorly drained and have become swampy "flatwoods."

On topographic maps of the Lissie areas it is possible to reconstruct the original flat depositional surface by drawing contours such as the heavy ones in Figures 5 and 6. These eliminate the post-Lissie gulleying and give a graphic view of the Lissie surface as it would appear now if no post-Lissie erosion had taken place. While the Lissie may never have been built up to this perfectly smooth surface, it was at least not built higher locally by deposition. The streams might have built distributary ridges on its surface but they could not build isolated local high areas. Such irregularities as shown by the Lissie 80-foot contour around the Humble dome, and by the 120-foot contour around the Orchard dome (Fig. 5), record local uplift of the Lissie surface over those domes.

Detailed mapping of the Lissie surface has shown only a few of these topographic anomalies in this area. Of these, one is located over a suspected salt dome and several are over or near proved oil fields.

In the town of Humble, in Harris County, the topography rises to elevations slightly above 90 feet. The Lissie contours in Figure 5 show that the normal Lissie surface should be about 80 at this point, indicating a post-Lissie uplift over the Humble dome of about 10 feet. Since this dome is located on the banks of the San Jacinto River local erosion has probably been accelerated, and the anomaly has possibly

been lowered slightly. The locally rough topography makes it impossible to observe the small abnormal elevation except by a reconstruction on a topographic map.

Figure 6 shows a prominent topographic high over the Saratoga field. The hills in the east edge of the field rise to elevations of 115 feet, while the Lissie contours show that the normal Lissie surface should be no higher than about 90. A post-Lissie uplift of 25 feet is indicated.

In southwest Louisiana, a small uplift in the Lissie surface is indicated by locally high topography north of the new Gillis field, immediately northeast of Lake Charles. This topography is too high to be Beaumont, and is slightly high for the Lissie. Erosion by the Calcasieu River which flows through this field may have removed a more prominent anomaly here.

Figure 5 shows a high point of topography crossing the Lissie 80-foot contour north of Eureka and northwest of Houston. This may be a reflection of the subsurface structure of the new Eureka field.

Other locally high features of topography are to be noted at Orchard and farther south in Wharton County. These, however, occur in Beaumont areas, and might be considered parts of Beaumont distributary ridges.

Some of the sections of the Lissie exposed in parts of the area where the local relief is greatest show ferruginous and clayey zones, and at a few points gravelly sands. These might be useful in mapping Lissie structure if they were more frequently exposed. However, most of the Lissie drains have rather flat profiles and do not give good sectional views of the formation. Contours which were drawn tentatively on occurrences of the ferruginous zone in the areas near the Sabine River seemed to give structural pictures which corresponded approximately with geophysical results. Whether these pictures represented true structure or simply coincided with the geophysical pictures accidentally can not be stated.

BEAUMONT SURFACE STRUCTURE

The mapping of the surface structure of the Beaumont requires the same treatment as applied to the Lissie areas. Generalized topographic maps or profiles must be prepared, from which the normal elevations of the top of the formation can be estimated. Any local area which rises conspicuously above this normal level is a prospect for further examination or for geophysical work.

In the Beaumont areas, however, the original depositional surface was never as smooth as that of the Lissie. The presence of remnants of distributary ridges with 10 or 20 feet of relief makes it somewhat

difficult to draw the normal contours for this surface, and makes it difficult to detect a general uplift occurring in a low spot between such ridges.

In the Beaumont area near the coast, so much intensive exploration by drilling and geophysical methods has already been done that the opportunity for discovery of new prospects by this surface method is somewhat limited. Surface reconnaissance is a cheaper substitute for geophysical reconnaissance. In this area the more expensive method has already been applied extensively.

FIG. 8.—Coarse phase of Willis gravels 5 miles southwest of Conroe on Tomball road.

FIG. 9.—Ferruginous nodules on surface of Willis ferruginous sand 2 miles north of Erin, Jasper County, Texas.

FIG. 10.—Ferruginous nodules on surface of Willis ferruginous sand north of Erin, Jasper County, Texas. Length of key, 2 inches.

FIG. 11—Unweathered 3-foot section of lower part of Willis sand member. Road cut just southeast of Erin, Jasper County, Texas.

FIG. 12.—Contact of Willis gravels on Fleming clays $1\frac{1}{2}$ miles north of Willis on Dallas highway. Mottled red sands covered with loose gravel in foreground. Clays in gully opposite car.

FIG. 13.—Upper part of Willis ferruginous sand in railroad cut south of Willis station.

FIG. 14.—Weathered Willis ferruginous sand in Willis railroad cut.

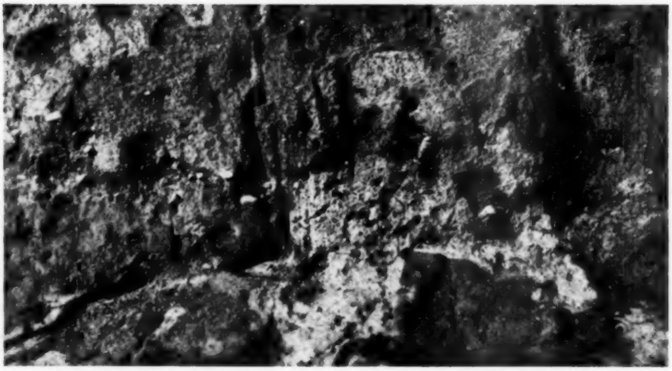

FIG. 15.—Willis gravelly sand 2 miles north of Erin, Jasper County, Texas, on Jasper highway. Gravel sizes up to ½ inch. Exposure is within 2 feet of top of member.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 689-695, 5 FIGS.

TENTATIVE FORAMINIFERAL ZONATION OF SUBSURFACE CLAIBORNE OF TEXAS AND LOUISIANA[1]

MERLE C. ISRAELSKY[2]
Houston, Texas

ABSTRACT

A tentative foraminiferal zonation for the Claiborne is offered. An attempt is made to demonstrate the desirability of using fossil zones rather than formations in long-distance correlation.

Correlation is a perplexing problem. The structural geologist dealing with sedimentary strata desires and needs dependable datum planes. For his basis of correlation he must use either lithology or fossils. Locally, lithology may be the more useful; over a distance the use of fossils seems much more satisfactory. Consideration will demonstrate that the limits of appearance or disappearance of a fauna will more nearly *approximate* a *time* plane than the lower or upper limits of a lithologic unit.

On the hypothetical dip-section, formational names are shown as used by Plummer.[3] It will be noted that the upper and lower limits of these lithologic units transgress the planes marked by fossils.

In this tentative zoning only the upper ranges are used because so few wells are sufficiently cored to establish the planes of appearance. Had we data for the lower ranges, a clearer interpretation might possibly be made.

In deciding on microfossils to use for zoning, we should choose, so far as possible, those having a wide geographic range and not being subject to the influence of very minor fluctuations of temperature (depth). If the fossil was also able to live on different types of bottom, so much the better. Of those species used herein, all, with the probable exception of *Textularia smithvillensis*, are found from southwest Texas to Alabama. Only *Eponides yeguaensis* and *Ceratobulimina*

[1] Published by permission of J. S. Ivy, United Gas Public Service Company, Houston, Texas. The part dealing with Texas was read before the Paleontology Division of the Association at the Dallas meeting, March 23, 1934; completed paper first read before the Shreveport Geological Society, December 7, 1934. Manuscript received, February 13, 1935.

[2] United Gas System, Box 2492.

[3] F. B. Plummer, *Univ. Texas Bull. 3232* (August, 1932), p. 528, Fig. 29.

eximia are consistently found in marine strata of either a sandy, clayey, or calcareous nature; the others appear to have preferred clayey or calcareous bottoms.

The *Foraminifera* used are the following, given in the order of their appearance in drilling; no attempt of a complete synonymy is made.

NONIONELLA COCKFIELDENSIS Cushman and Ellisor

Nonionella cockfieldensis Cushman and Ellisor, *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4 (1933), p. 95, Pl. 10, Figs. 11 a–c.

This species has been included in the Claiborne only because A. C. Ellisor[4] omitted the zone characterized by it from the Jackson. The writer believes the zone between the top range of the *Nonionella cockfieldensis* and the top range of *Eponides yeguaensis* is more nearly related to the Jackson. The Cockfield formation of the Louisiana outcrop and the adjacent and equivalent Yegua of northeast Texas from which *Nonionella cockfieldensis* was described are essentially deltaic deposits having their inception in late Claiborne time and continuing into Jackson time.

EPONIDES YEGUAENSIS Weinzierl and Applin

Eponides guayabalensis var. *yeguaensis* Weinzierl and Applin, *Jour. Paleon.*, Vol. 3, No. 4 (1929), p. 406, Pl. 42, Figs. 2 a–c.

This variety of *Eponides guayabalensis* Cole survives higher in the column than either the typical form as figured by Cole or the variety figured by Cushman and Thomas.

CRISTELLARIA MEXICANA Cushman

Cristellaria mexicana Cushman, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 2 (1925), p. 299, Pl. 7, Figs. 1–2
Robulus mexicanus Cole, *Bull. Amer. Paleon.*, Vol. 14, No. 51 (December, 1927), p. 18, Pl. 1, Fig. 20.
Robulus mexicana var. *deusseni* Weinzierl and Applin, *Jour. Paleon.*, Vol. 3, No. 4 (1929), p. 394, Pl. 44, Figs. 8 a–b.
Robulus jugosus Cushman and Thomas, *Jour. Paleon.*, Vol. 4, No. 1 (1930), p. 36, Pl. 3, Figs. 4 a–b.

The writer regards *R. deusseni* as a more ornate, *R. jugosus* as a less ornate variation of *Cristellaria mexicana*. From *R. jugosus* with its few beads to *Cristellaria nudicostata* is but a step further. The latter, however, is treated as a separate species because of its apparent stratigraphic significance.

CERATOBULIMINA EXIMIA (Rzehak)

Ceratobulimina eximia Cushman and Harris, *Contrib. Cushman Lab. Foram. Res.*, Vol. 3, Pt. 4 (1927), p. 174, Pl. 29, Figs. 3–4; Pl. 30, Figs. 12–16.

[4] A. C. Ellisor, "Jackson Group of Formations in Texas with Notes on Frio and Vicksburg," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 11 (November, 1933), pp. 1293–1350.

Stadnichenko, *Jour. Paleon.*, Vol. 1, No. 3 (1927), p. 233, Pl. 38, Figs. 9–11.
Cushman & Thomas, *Jour. Paleon.*, Vol. 3, No. 2 (1929), p. 182, Pl. 24, Figs. 3 a–c.
Weinzierl & Applin, *Jour. Paleon.*, Vol. 3, No. 4 (1929), p. 407, Pl. 42, Figs. 3 a–b.
Rotalia dorri Cole, *Bull. Amer. Paleon.*, Vol. 14, No. 51 (1927), p. 29, Pl. 4, Figs. 5–6.

CRISTELLARIA NUDICOSTATA Cushman and G. D. Hanna

Cristellaria mexicana Cushman var. *nudicostata* Cushman & G. D. Hanna, *Proc. California Acad. Sci.*, 4 Ser., Vol. 16, No. 8 (1927), p. 216, Pl. 14, Fig. 2.
Robulus mexicanus var. *nudicostatus* Cushman & G. D. Hanna, *San Diego Soc. Natl. Hist.*, Vol. 5, No. 4 (1927), p. 45, Pl. 4, Fig. 2.

TEXTULARIA SMITHVILLENSIS Cushman and Ellisor

Textularia smithvillensis Cushman and Ellisor, *Contrib. Cushman Lab. Foram. Res.*, Vol. 9, Pt. 4 (1933), p. 95, Pl. 10, Figs. 10 a–b.

LAMARCKINA CLAIBORNENSIS Cushman

Lamarckina marylandica Cushman var. *claibornensis* Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 2, Pt. 1 (1926), p. 10, no fig.
Lamarckina claibornensis Cushman and Thomas, *Jour. Paleon.*, Vol. 3, No. 2 (1929) p. 180, Pl. 24, Figs. 1 a–c.
Lamarckina marylandica var. *yeguaensis* Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 2, Pt. 1 (1926), p. 10, no fig.; Vol. 2, Pt. 2 (1926), p. 10, Pl. 4, Figs. 1a–c.

No distinction has been made between the foregoing two variations in the present zoning. The form whose occurrence is shown on the Ray No. 39 chart happens to be *claibornensis*.

To date the genus has not been found by the writer in higher Claiborne strata than those shown. It is not clear why it is absent, and no great surprise should be occasioned if the genus were found higher. If such is the case, it is to be hoped a different variety will be found.

It is felt that, with more familiarity with the species in the strata under discussion, a finer zonation may be made. The data from which the accompanying sections have been drawn are routine commercial reports by W. H. Pattison, A. R. Mornhinveg, M. M. Kornfeld, and the writer. The earlier reported wells were re-examined for *Cristellaria mexicana* and *nudicostata*.

E. B. Hutson and George Schneider, of Shreveport, kindly supplied data which were useful in carrying the section into Louisiana. The interest and care taken in producing illustrations by E. D. Meredith, J. E. Welsh, D. J. Hofmann, and A. R. Peloquen, of the United Gas Public Service Company's mapping and reproduction department, are gratefully acknowledged.

EXPLANATION OF PLATES

Figure 1 shows the range of a number of species in the United Production Corporation's Ray well No. 39, which was used as the

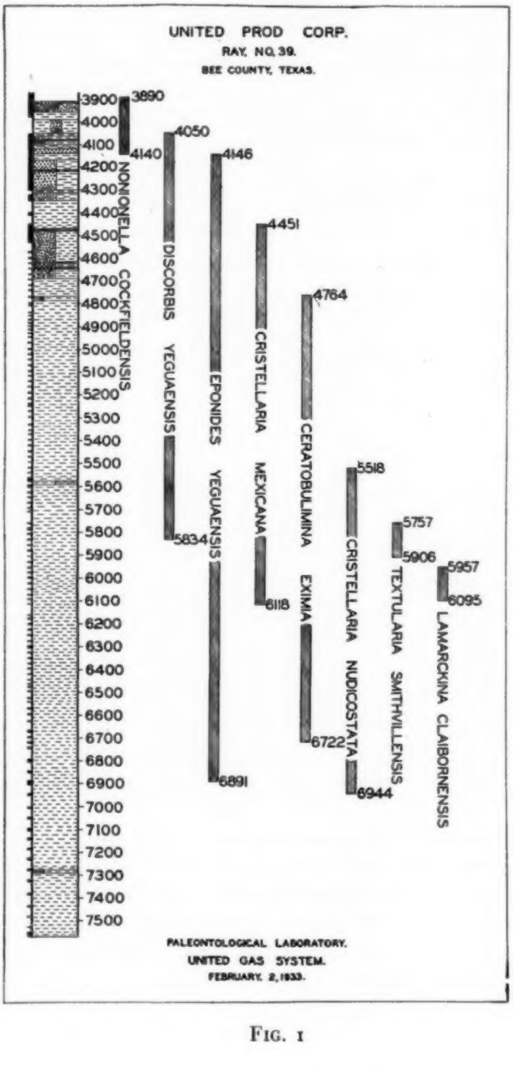
UNITED PROD CORP.
RAY NO. 39.
BEE COUNTY, TEXAS.
3900
4000
4100
4200
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
3890
4140
NONIONELLA COCKFIELDENSIS
4050
5834
DISCORBIS YEGUAENSIS
4146
6891
EPONIDES YEGUAENSIS
4451
6118
CRISTELLARIA MEXICANA
4764
6722
CERATOBULIMINA EXIMIA
5518
6944
CRISTELLARIA NUDICOSTATA
5757
5906
TEXTULARIA SMITHVILLENSIS
5957
6095
LAMARCKINA CLAIBORNENSIS
PALEONTOLOGICAL LABORATORY.
UNITED GAS SYSTEM.
FEBRUARY 2, 1933.

FIG. 1

section of reference. The core recovery is shown at the left of the geologic column.

Figure 2 shows the alignment of wells used in constructing the idealized sections. The wells were chosen, in so far as sample data permitted, to parallel the present outcropping Claiborne-Jackson contact as shown on latest maps.

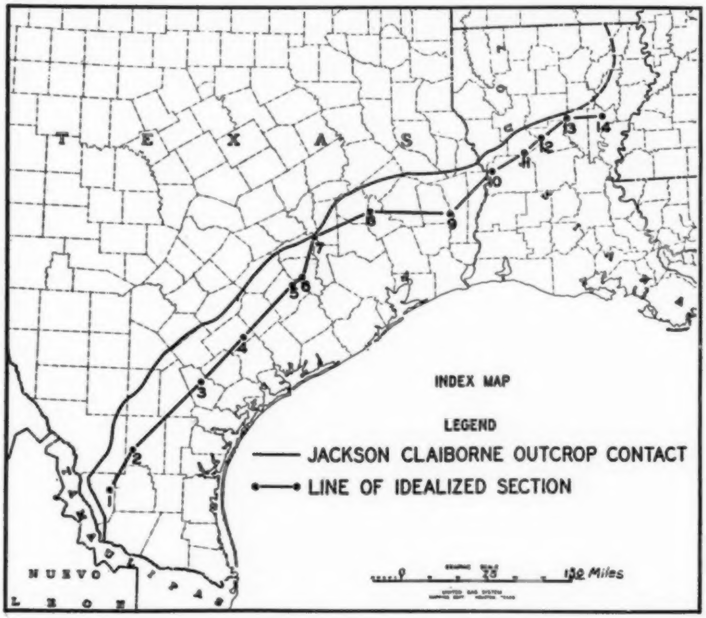

FIG. 2

In the idealized sections (Figs. 3 and 4) the base of the *Operculinella-Camerina* zone of the *Textularia dibollensis* zone of the Jackson, or the top range of *Nonionella cockfieldensis*, has been used as the upper limit.

Figure 3 extends from Zapata County to Tyler County, Texas. In well 1, large amounts of green and reddish mudstones occur between the base of the *Textularia dibollensis* zone of the Jackson and the upper range of *Ceratobulimina eximia*, with fossils extremely rare in this interval. The writer deduces that No. 1 was well within a delta at that time. The lower beds appear to be marine. No. 2 appears to

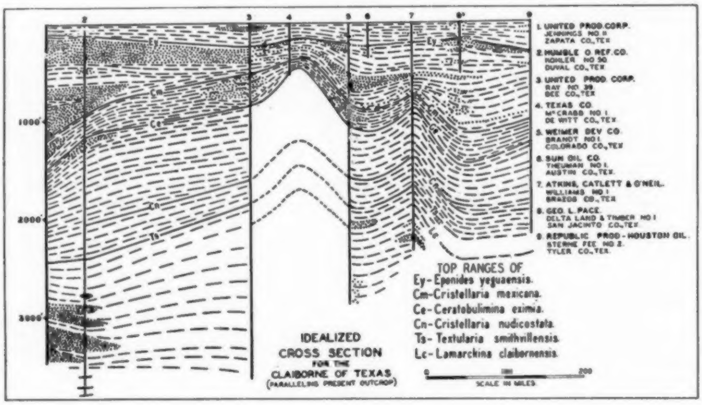
1. UNITED PROD. CORP.
JENNINGS NO 8
ZAPATA CO., TEX
2. HUMBLE O. REF. CO.
KOHLER NO 30
DUVAL CO., TEX
3. UNITED PROD. CORP.
RAY NO 39
BEE CO., TEX
4. TEXAS CO.
M^c CRABB NO 1
DE WITT CO., TEX
5. WEIMER DEV CO.
BRANDT NO 1
COLORADO CO., TEX
6. SUN OIL CO.
THEUMAN NO 1
AUSTIN CO., TEX
7. ATKINS, CATLETT & O'NEIL
WILLIAMS NO 1
BRAZOS CO., TEX
8. GEO. L. PACE
DELTA LAND & TIMBER NO 1
SAN JACINTO CO., TEX
9. REPUBLIC PROD.-HOUSTON OIL
STERNE FEE NO 2
TYLER CO., TEX
TOP RANGES OF
Ey-Eponides yeguaensis.
Cm-Cristellaria mexicana.
Ce-Ceratobulimina eximia.
Cn-Cristellaria nudicostata.
Ts-Textularia smithvillensis.
Lc-Lamarckina claibornensis.
IDEALIZED
CROSS SECTION
FOR THE
CLAIBORNE OF TEXAS
(PARALLELING PRESENT OUTCROP)
SCALE IN MILES

FIG. 3

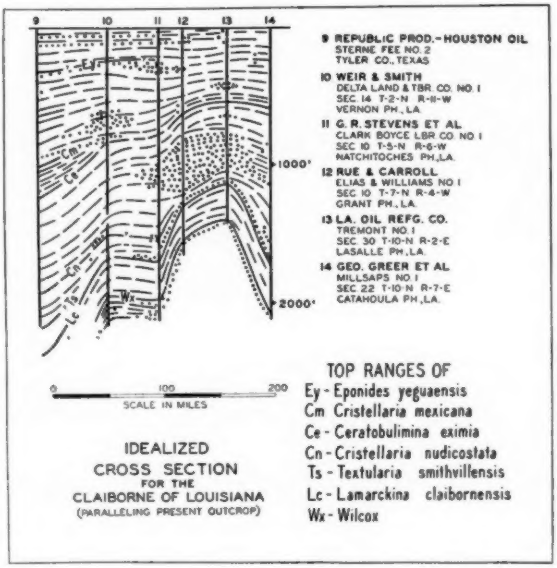
9 REPUBLIC PROD.-HOUSTON OIL
STERNE FEE NO. 2
TYLER CO., TEXAS
10 WEIR & SMITH
DELTA LAND & TBR. CO. NO. 1
SEC. 14 T-2-N R-11-W
VERNON PH., LA.
11 G. R. STEVENS ET AL
CLARK BOYCE LBR. CO. NO. 1
SEC. 10 T-5-N R-6-W
NATCHITOCHES PH., LA.
12 RUE & CARROLL
ELIAS & WILLIAMS NO. 1
SEC. 10 T-7-N R-4-W
GRANT PH., LA.
13 LA. OIL REFG. CO.
TREMONT NO. 1
SEC. 30 T-10-N R-2-E
LASALLE PH., LA.
14 GEO. GREER ET AL
MILLSAPS NO. 1
SEC. 22 T-10-N R-7-E
CATAHOULA PH., LA.
1000'
2000'
0 100 200
SCALE IN MILES
TOP RANGES OF
Ey - Eponides yeguaensis
Cm Cristellaria mexicana
Ce - Ceratobulimina eximia
Cn - Cristellaria nudicostata
Ts - Textularia smithvillensis
Lc - Lamarckina claibornensis
Wx - Wilcox
IDEALIZED
CROSS SECTION
FOR THE
CLAIBORNE OF LOUISIANA
(PARALLELING PRESENT OUTCROP)

FIG. 4

have been farther toward the delta's margin during that phase. Wells 3–9 are essentially marine throughout. Excellent suites of cores were available from wells 3 and 1, good samples from 2 and 9.

The rest of the section (Fig. 4), wells 10–14, is somewhat impressionistic, no satisfactorily sampled wells being available to the writer and the conception being based on scattered samples.

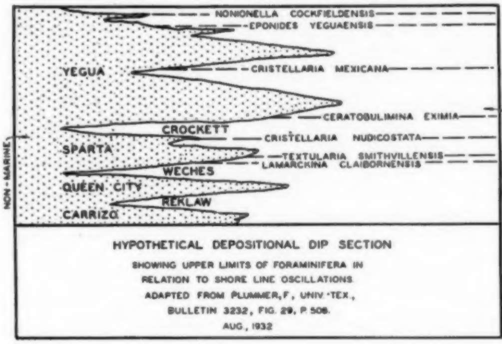

FIG. 5

The depression of the upper ranges of *Eponides yeguaensis*, *Cristellaria mexicana*, *Cristellaria nudicostata*, and *Textularia smithvillensis* as No. 12 is approached, is considered due to the more nonmarine character of the zones they characterize under purely marine conditions.

The hypothetical depositional dip section (Fig. 5) is self-explanatory.

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VOL. 19, NO. 5 (MAY, 1935), PP. 696-702, 1 FIG.

GEOLOGICAL NOTES

STRATIGRAPHY OF MIDWAY GROUP (EOCENE) OF SOUTHWEST ARKANSAS AND NORTHWEST LOUISIANA[1]

The Midway group in Texas has recently been extensively subdivided. Julia Gardner has proposed the name Kincaid[2] for the "lower Midway" of earlier writers, and the name Wills Point, applied by Penrose[3] to the Midway of Texas, and later rejected as a synonym for the earlier name, has been restricted and applied as a formation name to the upper Midway clays[4] which crop out in the vicinity of Wills Point, Van Zandt County, Texas. F. B. Plummer[5] has further divided the Kincaid formation into (1) the Littig glauconite member, a bed of glauconite and sand ranging from 8 inches to 15 feet thick at the base of the formation, and (2) the Pisgah member, which includes the overlying clays, glauconitic clays, sands, and limestone lentils, and has likewise divided the Wills Point formation into (1) the Mexia clay member, consisting of fossiliferous clays, with a thin, glauconitic sand at its base, (2) the Wortham aragonite lentil, a persistent stratum only 8–10 inches thick, and (3) the Kerens clay member, consisting of dark gray, silty or sandy clays.

The study of samples from numerous wells drilled in southwest Arkansas and northwest Louisiana has convinced the writer that it is possible to identify, in the Midway section of that area, the principal subdivisions of the group now recognized in Texas. These correlations are based upon the ranges of the *Foraminifera* as described by Helen Jeanne Plummer in the Texas Midway.[6]

Most of the material examined in this study has been derived

[1] Manuscript read before the Paleontology Division of the Association at Wichita, March 23, 1935. Published by permission of the Magnolia Petroleum Company.

[2] Julia Gardner, "Kincaid Formation, Name Proposed for Lower Midway of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 6 (June, 1933), p. 744.

[3] R. A. F. Penrose, "A Preliminary Report on the Geology of the Gulf Tertiary of Texas, from Red River to the Rio Grande," *Texas Geol. Survey Ann. Rept. 1* (1889), p. 19.

[4] F. B. Plummer, "The Geology of Texas—Cenozoic Systems," *Texas Univ. Bull. 3232* (1933), p. 555.

[5] *Ibid.*, pp. 536, 559.

[6] Helen Jeanne Plummer, "Foraminifera of the Midway Formation in Texas," *Texas Univ. Bull. 2644* (1926).

from well cuttings, since very few of the wells drilled in southwestern Arkansas and northern Louisiana are cored in formations above the Nacatoch. Occasional cores from the Midway have, however, been available, and the Gulf Refining Company has generously allowed the writer to examine samples from its Luther Ford No. 1, Sec. 8, T. 22 N., R. 13 W., Bossier Parish, Louisiana, and from its Tom

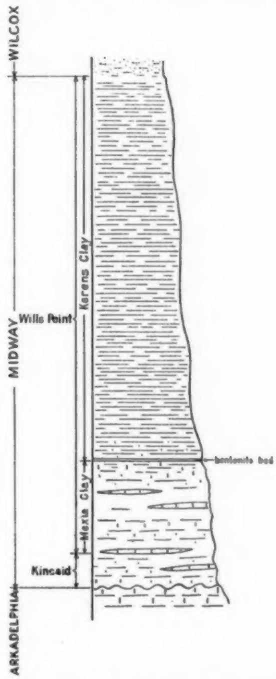

FIG. 1.—Generalized section of Midway of southwest Arkansas and northwest Louisiana, showing subdivisions and correlation with Texas section.

Critchton No. A-1, Sec. 15, T. 18 N., R. 9 W., Webster Parish, Louisiana, in both of which unusually complete sets of cores were taken in the lower, calcareous portion of the Midway.

Moody[7] has described the Midway of the region of the Sabine Uplift as follows.

> The lower part of the Midway group is chiefly calcareous, with true chalk occurring as lenses in Arkansas and Louisiana. . . . In later Midway time,

[7] C. L. Moody, "Tertiary History of Region of Sabine Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 5 (May, 1931), p. 539.

limy material reached the sea in less and less quantity until only finely divided terrigenous detritus was deposited. Marine life also became more impoverished and finally ceased to exist in the embayment region.

The Midway group ranges in thickness in southwest Arkansas and northwest Louisiana from about 400 to 600 feet, the basal, calcareous portion from 40 or 50 to about 100 feet. The change from the calcareous, marly or chalky, shales of the lower Midway to the dark, steel-gray, finely laminated, silty shales or mudstones of the upper Midway, is apparently transitional, as implied by Moody, but appears to take place in a relatively short interval.

Spooner[8] states that

> Through most of southern Arkansas the contact between the Midway and the underlying Cretaceous is marked by a bed of white to gray ash, having a maximum observed thickness of approximately 6 feet.

This bed of volcanic ash appears in well cuttings as flakes of bluish or greenish gray bentonite, and has been extensively used as a marker of the Midway-Cretaceous contact. In all the wells examined by the writer in southwestern Arkansas and northwestern Louisiana, however, this bentonite bed lies either at the top, or in the uppermost part of the lower, calcareous section of the Midway.

The only microfossils observed by the writer in the upper, silty, non-calcareous Midway shales of this region are small species of *Ammobaculites* and *Spiroplectammina*. None of the specimens discovered could be definitely identified with the species of these genera described by Mrs. Plummer from the uppermost Midway of Texas.[9]

As the lower, calcareous shales of the Midway are reached in drilling wells, a few hyalin *Foraminifera* begin to make their appearance. The first species observed are, as a rule, *Anomalina midwayensis* Plummer, *Eponides tenera* (H. B. Brady), *Cibicides alleni* (Plummer), and *Globigerina triloculinoides* Plummer. Highly calcareous shales, commonly marly or chalky in character, and rich in microfauna, are usually encountered within a few feet, after the first hyalin *Foraminifera* appear. The upper part of this calcareous section yields a typical Wills Point assemblage of *Foraminifera*. *Anomalina vulgaris* (Plummer), *Pulvinulinella culter* (Parker and Jones), *Vaginulina robusta* Plummer, and other species usually make their appearance slightly below those previously listed.

The lower portion, ranging from approximately one-third to one-

[8] W. C. Spooner, "Oil and Gas Geology of the Gulf Coastal Plain in Arkansas," *Arkansas Geol. Survey Bull.* (2), 1935, p. 117.

[9] Helen Jeanne Plummer, "Foraminiferal Evidence of the Midway-Wilcox Contact in Texas," *Texas Univ. Bull. 3201* (1935), pp. 51–68; Pl. 5.

fourth of the calcareous section of the Midway, contains *Vaginulina gracilis* Plummer, *Astacolus pseudocostata* (Plummer), *Anomalina midwayensis* var. *trochoides* Plummer, and *Eponides exigua* (H. B. Brady) var. *limbata* (Plummer), species characteristic of the Kincaid formation of Texas.

As in the Texas Midway, there is a faunal "transition zone" in which the Kincaid and Wills Point faunas overlap. Cores from this zone, from wells in southwest Arkansas and northwest Louisiana, contain a mixture of Kincaid and Wills Point species, including both *Vaginulina gracilis* and *V. robusta*.

A species of *Lituola* which is closely similar to, if not actually identical with, *L. taylorensis* Cushman and Waters, originally described from the Taylor formation in Texas[10] and recorded from the Annona chalk in Arkansas and Texas,[11] appears to occur throughout this region in the Kincaid, and in the transition zone between the Kincaid and Wills Point. The specimens do not appear to be reworked, and their abundance and wide distribution further suggest that they lived at the time the sediments containing them were deposited.

In conclusion, it may be stated that both the Kincaid and Wills Point formations are represented in the Midway of southwest Arkansas and northwest Louisiana; and further, it seems reasonable to suggest that the upper, silty, non-calcareous shales of the Wills Point of this area are approximately equivalent to the Kerens clay of Texas, and that the lower, calcareous Wills Point shales, marls, and chalky shales are correlative with the Mexia clay.

C. I. Alexander

Magnolia Petroleum Company
Shreveport, Louisiana
March 8, 1935.

MIGRATION OF OIL IN OKLAHOMA CITY FIELD

Certain parts of the "Wilcox" area of the Oklahoma City field give us a very good illustration of the ease with which oil can migrate through a porous sand. In the W. ½ of the NW. ¼ of Sec. 2, T. 11 N., R. 3 W., 34 wells were drilled during the development of the Oklahoma City field. All of these wells penetrated the base of the "Wil-

[10] Joseph A. Cushman and James A. Waters, "Some Arenaceous Foraminifera from the Taylor Marl of Texas," *Contrib. Cushman Lab. for Foram. Research*, Vol. 5 (1929), p. 66, Pl. 10, Figs. 7a–e.

[11] Joseph A. Cushman, "The Foraminifera of the Annona Chalk," *Jour. Paleont.*, Vol. 6 (1932), p. 133.

cox" sand which makes it possible to calculate the total sand volume. This volume amounts to 8,200 acre-feet. The average porosity of the "Wilcox" sand in the northern part of the field is approximately 22 per cent. A porosity of 22 per cent corresponds with a pore volume of 1,708 barrels per acre-foot of sand. One acre-foot could therefore have contained not more than 1,708 barrels of oil. The 1,708 barrels of oil saturated with gas under the conditions originally existing in the Oklahoma City field correspond with about 1,200 barrels of oil after production, the loss being due to shrinkage caused by liberation of gas dissolved in the oil, and calculated by the United States Bureau of Mines to be about 30 per cent for Oklahoma City crude.

The total production of the 80 acres to September 1, 1934, was 16,585,373 barrels, as reported to the Oklahoma State Corporation Commission, and more if all the oil illegally produced were taken into consideration. The 16,585,373 barrels correspond with a production of 2,020 barrels per acre-foot. Since the original oil content per acre-foot was at the most 1,200 barrels, it is evident that a great amount of migration must have taken place to produce 2,020 barrels. This oil unquestionably came from the undrilled "Wilcox" area under Oklahoma City about half a mile northwest.

It is interesting to note that in spite of the great production obtained from these particular 80 acres, the average well in this tract produced 6,100 barrels during August, 1934, while the average "Wilcox" well of the Oklahoma City field produced 6,650 barrels. In other words, these wells have about the same average production as the rest of the wells in the "Wilcox" zone. Out of 34 wells only two were not able to make their August allowable. The bottom-hole pressure in the W. ½ of the NW. ¼ of Sec. 2 was, in August, 1934, only 100–200 pounds lower than the bottom-hole pressure at the edge of the undeveloped area, showing that a pressure drop of 100–200 pounds in half a mile was sufficient to supply a daily production varying from 6,000 to 7,000 barrels to the area under consideration.

While these observations have primarily a bearing on the movement of oil in producing fields they are also of significance with regard to migration of oil prior to accumulation. For they demonstrate the great permeability of the "Wilcox" sand and the ease with which oil can move through this sand in spite of the smallness of the pressure gradient. If we take further into consideration that the "Wilcox" sand is a typical blanket sand which extends over a large part of Oklahoma and of some of the adjoining states, the rich oil accumulation in this sand in the Oklahoma City and Seminole districts assumes a new significance. This is particularly true if we contrast with these

oil deposits the absence of prolific accumulation in the more lenticular Pennsylvanian sands which, even in small areas, lack the continuity of the "Wilcox" sand. These conditions suggest very strongly a long-distance migration of oil in the "Wilcox," resulting in large accumulations, while in the more discontinuous Pennsylvanian sands the migration was more restricted, with the result that only minor oil deposits formed on even such pronounced structures as the Oklahoma City anticline. This theory is further borne out by the fact that oil in the "Wilcox" sand in the Oklahoma City district is invariably associated with structures, though the Pennsylvanian sands yield, in various places, commercial production off structures. That oil has at one time also been present in the "Wilcox" sand away from structures is indicated by the fact that many dry holes found traces of oil in the dolomites and sandy dolomites above the "Wilcox." These dolomites have a rather irregular and discontinuous porosity so that small amounts of oil may have been trapped at any place, while in the more permeable and continuous "Wilcox" sand, all of the oil originally present has migrated to structures.

Though these observations do not give any clue about the maximum distance of migration, the writer believes that once the possibility of migration is conceded, the distance of migration is only a function of time, continuity of dip and sand, but independent of distance. In case of a blanket sand, like the "Wilcox" sand, we may therefore reasonably expect a large drainage area which, in the Oklahoma City field, may well have extended into the Anadarko basin, a distance of perhaps more than 100 miles. This is the more probable, as a blanket sand has been deposited either in an advancing or receding sea, in other words, as the entire blanket sand has been laid down under similar conditions. If, therefore, the prerequisites for the deposition of source beds in connection with a blanket sand were given in one place, it seems logical that the same or similar conditions should have followed or preceded the transgressing or receding sea and be found regardless of structures in the whole area covered by the blanket sand, a stipulation fully borne out by the lithologic consistency in wide areas of the Simpson formation.

It is probably more than a coincidence that the richest fields in Texas are associated with the Woodbine sand, another blanket sand, and that they, like the Seminole and Oklahoma City fields, occur at locations with large potential drainage areas.

R. W. Brauchli

Oklahoma City, Oklahoma
March 12, 1935

THOROLD SANDSTONE

To correct a faulty idea, which the writer has helped to perpetuate, the following facts should be made known. In the Niagara gorge, the Silurian red Medina (Grimsby) sandstones are capped by 8 feet of "white" Thorold sandstone, carrying *Arthrophycus*. In the Genesee gorge at Rochester, 74 miles east, the red Medina beds are topped by 3 feet of "white" sandstone, without *Arthrophycus*, which also has been called "Thorold" and was so assigned in my paper of 1918[1]—but with this footnote, in part.

There may be a question as to the identity of the "gray band" at Rochester with the Thorold sandstone. Observers agree that the true Thorold is closely linked to the subjacent red beds, whereas the converse is true of the gray sandstone at Rochester. This matter requires investigation.

In a subsequent visit to Medina, between Rochester and Niagara, with Herbert P. Woodward, we found there both beds, the "gray band" of Rochester above, with several feet of green shale beneath it, and below this the *Arthrophycus* (Thorold) sandstone. But the latter was splotched with red. This intervening green shale, though not present in the Rochester gorge, is seen again below the "gray band" at Glen Edyth, 6 miles farther east; is probably also the green shale reported by Murray above the Thorold at the Welland canal, mentioned in tbe same footnote as possibly Maplewood shale. Its discontinuity bespeaks a disconformity at close of the Medina, rather than at close of the Maplewood.

The true Thorold sandstone, if present at Rochester gorge and Glen Edyth, as seems inevitable, has become wholly red and is the 7-foot top bed of the red Medina there, the bed that carries *Arthrophycus*, with the "gray band" sharply disconformable above it in the gorge, though some red sand has been worked up into the base of the latter.

Thus the "gray band" at Rochester is not the Thorold, for which it has been mistaken. The Thorold is a part of the Medina. The "gray band" of Rochester is a western finger of the Oneida sandstone and conglomerate, still containing an occasional quartz pebble, and is a part of the Clinton group, grading upward into the Maplewood shale. Since the latter is also probably Oneida, the "gray band" may well receive the local designation, *Kodak* white sandstone, with its type exposure in the lower Genesee gorge from the lower falls to Kodak Park, in the city of Rochester, New York.

GEORGE H. CHADWICK

175 BRIDGE STREET
CATSKILL, NEW YORK
APRIL, 1935

[1] G. H. Chadwick, *Bull. Geol. Soc. America*, Vol. 29 (1918), pp. 327–68, footnote 334.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 703-704

DISCUSSION

OCCURRENCE OF BACULITES OVATUS ZONE OF UPPER ALBERTA SHALES IN SOUTHEASTERN BRITISH COLUMBIA

Olsson and Caster[1] have made a valuable contribution to knowledge of Upper Cretaceous stratigraphy and paleontology in the Canadian Rocky Mountain region. The discovery of *Baculites ovatus* and the associated fauna in the Flathead River area, beneath the fault plane of the great Lewis overthrust, aids in filling the gap between the hitherto farthest southwest recorded occurrence of this fauna in Alberta, and the northern Montana localities. The assemblage of fossils reported including, as it does, *Inoceramus lundbreckensis*, *Ostrea congesta* and *Anomia* sp., suggests to the present writer a horizon low down in the *B. ovatus* zone.

Olsson and Caster suggest that the shore line of the Cretaceous sea during Upper Alberta time "was presumably several miles west of the present outcrop of these beds and therefore well within the area of the present Rocky Mountains." In the opinion of the present writer, if the tremendous foreshortening of strata in the foothills belt and the eastern mountain ranges—due to intense folding and overthrusting in a west-to-east direction—were ironed out, then the present western margin of outcrop of the marine Cretaceous beds would be moved many miles westward. Judged by the character of these marine deposits, the actual shore line must have been still many miles farther west.

In the note by Olsson and Caster, there are a few inaccuracies or misinterpretations of points in the paper by Webb and Hertlein[2] which are indicated and corrected in the order in which they appear in the note as follows.

Page 295. "The Alberta shale embraces the Colorado (Benton) and Montana series, . . ."

The Alberta shale includes only the basal part of the Montana series, which is, in the foothills, the upper part of the Wapiabi formation. The overlying Belly River strata, and the marine Bearpaw shale above these freshwater beds, are all of Montana age.

Page 296. "The Cardium sandstone initiated the deposition of the Wapiabi monothem."

This statement imparts quite the wrong idea, because the Cardium, if to be related to either shale series, represents the culmination of a shallowing of the Blackstone sea, the shale deposits of which grade into the Cardium

[1] "Occurrence of Baculites Ovatus Zone of Upper Alberta Shales in Southeastern British Columbia," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 2 (February, 1935), pp. 295–99.

[2] J. B. Webb and L. G. Hertlein, "Zones in the Alberta Shale in the Foothills of Southwestern Alberta." *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 11 (November, 1934).

sandstones. The renewal of shale deposition at the beginning of Wapiabi time seems to mark a rapid change to deeper-water conditions again.

Page 296. "In 1914 Cairnes delimited the name (Cardium) to supplant the preoccupied name Big Horn sandstone which Malloch had used for the basal Wapiabi member."

This information is entirely incorrect and it is difficult to understand where such an impression could be obtained. Cairnes had nothing to do with the re-naming of the Bighorn formation. This matter is fully discussed in the paper by Webb and Hertlein. Further, the Bighorn has never been regarded as the "basal member" of the Wapiabi formation. Malloch classed it as a separate formation and so it has remained.

Page 297. Olsson and Caster state that McLearn reports *Baculites ovatus* from the Crowsnest area, a statement based on misunderstanding of McLearn's report. The latter suggested the equivalence of his *Inoceramus lundbreckensis* fauna, which is common in the Crowsnest area, with the well known *B. ovatus* fauna occurring in the foothills farther north in Alberta, but the latter species itself was not found in the south.

J. B. Webb

29 Wilburton Road
Toronto, Ontario
March 1, 1935

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 705-760, 9 FIGS.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Chester Franklin Barnes, Houston, Tex.
T. F. Petty, L. T. Barrow, J. E. LaRue
Loren I. Buck, Tulsa, Okla.
Richard T. Lyons, Richard B. Rutledge, Joseph E. Morero
Carle Hamilton Dane, Washington, D. C.
Arthur A. Baker, Hugh D. Miser, John B. Reeside, Jr.
Albert Ingstrup Gregersen, Los Angeles, Calif.
R. D. Reed, H. W. Hoots, R. M. Barnes
Roger Henquet, Long Beach, Calif.
R. W. Sherman, R. G. Greene, E. L. Ickes
Vincent Charles Illing, London, England
A. R. Denison, E. DeGolyer, George M. Lees
Marcellus Leslie Kerlin, Jr., San Angelo, Tex.
Paul B. Hunter, Ernest A. Obering, Kenneth S. Ferguson
Clarence Ziegler Leonard, Houston, Tex.
J. Harlan Johnson, A. W. Lauer, J. N. Troxell
Charles Culberson Mason, Caripito, Venezuela, S. A.
G. Moses Knebel, John W. Brice, Roger H. Sherman
James Michelin, Long Beach, Calif.
Glenn H. Bowes, R. M. Barnes, Harold W. Hoots
Gerald Hugh Scott, Trinidad, B. W. I.
H. G. Kugler, E. Lehner, G. W. Halse

FOR ASSOCIATE MEMBERSHIP

Bernard E. Curran, Oil City, Pa.
John G. Douglas, Chester A. Baird, P. E. Nolan
William Reese Dillard, Tulsa, Okla.
W. C. Adams, L. E. Kennedy, C. A. Warner
William Clayton Fritz, Midland, Tex.
James FitzGerald, Jr., E. Russell Lloyd, Cary P. Butcher
J. E. Heston, New York, N. Y.
E. P. Hindes, V. E. Monnett, Charles E. Decker
Ralph G. Hubman, Maracaibo, Venezuela, S. A.
J. B. Burnett, E. S. Neal, J. L. Kalb

Claude M. Langton, Laredo, Tex.
Fred P. Shayes, D. G. Barnett, Charles A. Stewart
James Sargent Lock, Jacksonville, Tex.
Norman L. Thomas, James W. Kisling, Jr., Wallace Ralston
Robert D. Ohrenschall, Wichita, Kan.
W. B. Heroy, John R. Sandidge, Joseph T. Singewald, Jr.
Raymond D. Sloan, Wichita, Kan.
M. A. Dresser, V. E. Monnett, D. C. Nufer
Randall Wright, Ventura, Calif.
T. Wayland Vaughan, D. Jerome Fisher, Carey Croneis

FOR TRANSFER TO ACTIVE MEMBERSHIP

William Henry Courtier, Washington, D. C.
Arthur A. Baker, Hugh D. Miser, Thomas H. Allan
Clarence Ferrero, Houston, Tex.
John C. Myers, W. F. Bowman, A. I. Levorsen
Donald Goodwill, Jr., New Orleans, La.
A. F. Crider, Clarence O. Day, R. B. Grigsby
Edward A. Koester, Wichita, Kan.
C. J. Stafford, E. C. Moncrief, L. C. Morgan
Robert C. Lafferty, Jr., Charleston, W. Va.
Otto Fischer, Victor Cotner, H. E. Crum
Riley Glen Maxwell, San Angelo, Tex.
W. C. Kinkel, Edward T. Merry, William M. Nicholls
Virgil Harold Welch, Shawnee, Okla.
Jack M. Copass, Dollie Radler Hall, Jess Vernon

TWENTIETH ANNUAL MEETING
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
ALLIS HOTEL, WICHITA, KANSAS, MARCH 21–23, 1935

The twentieth annual meeting was a success. It was exactly like each of the preceding nineteen; it possessed its own peculiar and superlative features which made it satisfyingly distinct and different. It was the same thing with a difference. The same sweetheart in another mood and a new gown. The same old rockhound in another field.

The Allis was headquarters—full to overflowing. As one pushed through the Broadway entrance and came up to the lobby floor, the feeling unquestionally was that of having arrived. This was it: the difficulty of proceeding farther without dispute, arbitration, and coöperation; the obliterating buzz of many voices; the effort to locate a buddy who was right here a minute ago, but not now; the flags over the mezzanine railing; the banners of other cities seeking next year's convention; and there on a slight elevation above the stairs, "A.A.P.G. Register Here."

The long registration counter with a row of busy men and women behind clicking typewriters, writing names, handing out badges and programs, making reservations for dinners, dances, luncheons, golf matches, field trips, and what not—this was the beginning, the source of information. At the right —the business office of the local committee in charge of plans and activities, the place where announcements originated for the bulletin board in plain view just outside the door, the place where orders were given for more chairs

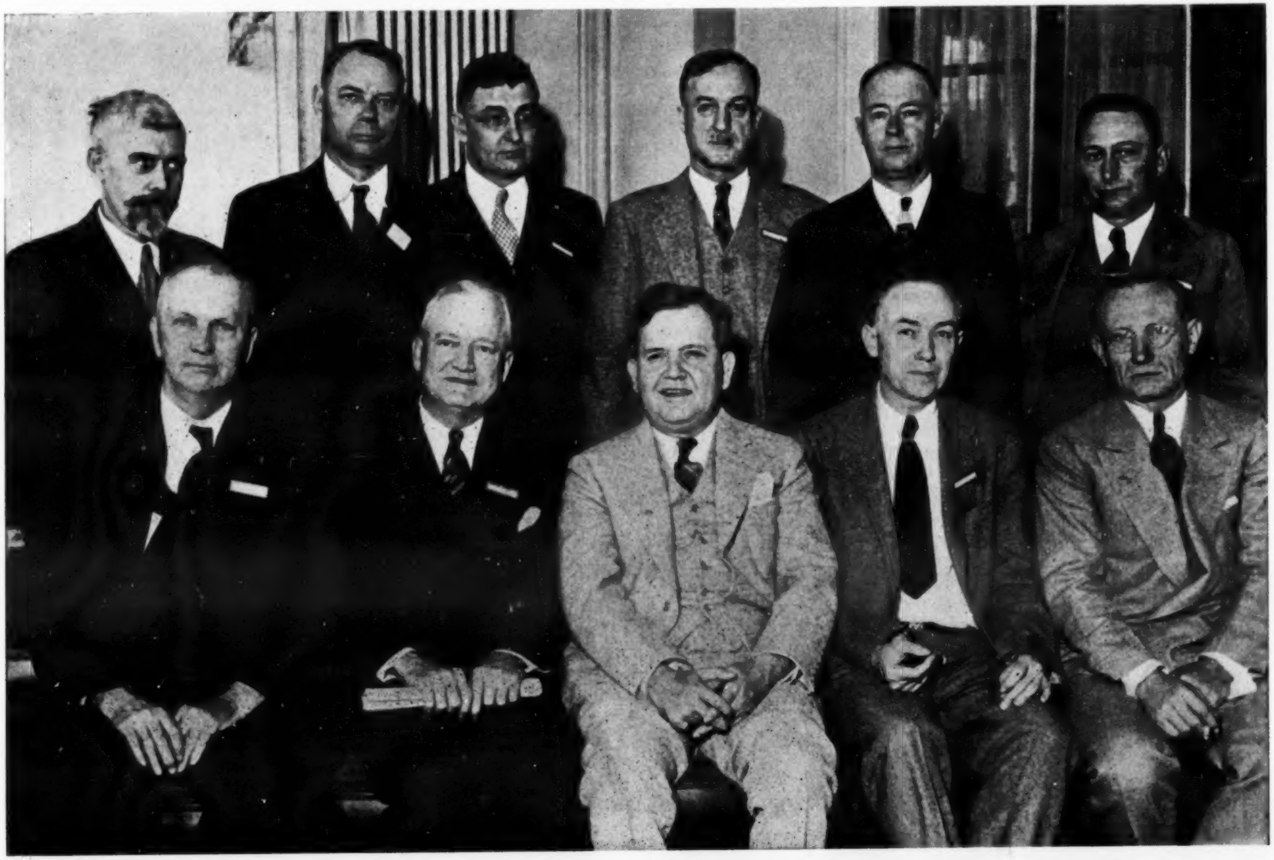

FIG. 1.—Geologists who attended first annual meeting of American Association of Petroleum Geologists at Norman, Oklahoma, January 7–8, 1916. Photograph of a few of the founders taken at twentieth annual meeting of the Association, at Wichita, Kansas, March 21–23, 1935. Standing, left to right: Ed. Bloesch, Charles R. Eckes, Harry F. Wright, Jerry B. Newby, Fritz Aurin, Robert E. Garrett. Seated, left to right: Charles N. Gould, Wallace E. Pratt, E. L. DeGolyer, Irving Perrine, Alex. W. McCoy. Photo by *Wichita Beacon*.

FIG. 2.—Past-presidents of Association present at twentieth annual meeting, Wichita, Kansas, March 21–23, 1935. Standing, left to right: E. L. DeGolyer, elected president at Wichita, 1925; Frank R. Clark, elected at Houston, 1933; Frederic H. Lahee, elected at Oklahoma City, 1932; William B. Heroy, at Dallas, 1934. Seated, left to right: George C. Matson, at Tulsa, 1921; W. E. Wrather, at Oklahoma City, 1922; Wallace E. Pratt, at Dallas, 1920. Other past-presidents attending Wichita meeting were Alexander Deussen, elected at Oklahoma City, 1918, and Alex. W. McCoy, elected at Dallas, 1926, A more complete group of past-presidents, as photographed at Dallas in 1934, is shown in the June, 1934, *Bulletin*, pages 832–3.

for the meeting rooms, more signs for the exhibitors, more places at the banquet, more tickets for the dance,—the office of the trouble shooter.

At the south end of this long information center was another local committee room where the ladies kept the phones busy speeding their arrangements for musicale, luncheon, and special entertainment. Near by, the Association headquarters table, where dues might be paid and publications examined. And beyond a large and brightly illumined oil-field map of Kansas, was the entrance to the Ball Room, where the technical sessions were in progress. The presentation of a restricted number of papers for oral delivery and discussion continues to meet the approval of the members, and though this requires good judgment, fairness, firmness, and patience on the part of the program chairman, the satisfactory sequence and punctual dispatch which characterized this program indicated its success and rewarded the labors of the local committee.

At the north side of the central lobby, the beautiful high-ceiled, lofty-windowed dining rooms were given over to the laboratory and field equipment displays. Alidades, compasses, maps, well logs, core bits, microscopes, seismographs, torsion balances, acid treatment, and air photography offered a speedy post-graduate review epitomizing the progress and variety of geological work.

On the mezzanine, divisional sessions in paleontology, mineralogy, and geophysics were held in the Aviation Room.

At the Innes Tea Room, the ladies were privileged to attend a musicale by Dean Thurlow Lieurance of Wichita University, and at the Lassen Hotel nearly 250 ladies sat down to the luncheon in the Ball Room.

The banquet and dance, with accompanying orchestra and midnight floor show, were staged at the Broadview Hotel. The photograph seems sufficient evidence that there really was a banquet, and one of some size; also, about 800 participants might be called as witnesses of the event; but it is doubtful if full agreement could be had as to exactly what transpired at the gay scene. For example, it is reported that Ellick Botts, of Gray Horse, Oklahoma, alias Larry Smith, of a national oil-trade journal, was present in person at the speakers' table; in fact, that he delivered a speech; but others present stoutly affirm not only that they heard nothing of Mr. Botts, but that there was no speakers' table. Such testimony must of course be accepted with some reservation. The writer was at said banquet until the late hour of 10:30 P.M. and it is his personal knowledge that several persons were speaking at once during the event and it is barely possible that those at one end of the hall might not have recognized Mr. Botts' voice. Those present will recall that it was a good fraction of a mile from the ticket gate to where the speakers' table was reported to have been located.

This matter of the annual banquet is a large and ramifying subject, and somewhat puzzling to a few abstract philosophers over 40 who still carry umbrellas when it rains. Be that as it may, banquets seem to be back to stay. The supply of tickets gave out at Wichita. The majority must be right. They held the floor till morning.

Annual meetings well nigh defy satisfying description in ordinary prose. The reporter should be part poet, painter, statistician, as well as geologist. The usual statistics and reports follow,—with a few photographs if you don't like figures.

FIG. 3.—Association banquet on Broadview Roof, twentieth annual meeting, Wichita, Kansas, March 22, 1935. Photograph shows only beginning of event. Reputed location of speakers' table and Ellick Botts, consulting pumper of Gray Horse, Oklahoma , and guest speaker at banquet, is obscured in western Kansas dust cloud at far end of room.

FIG. 3.—Association banquet on Broadview Roof, twentieth annual meeting, Wichita, Kansas, March 22, 1935. Photograph shows only beginning of event. Reputed location of speakers' table and Ellick Botts, consulting pumper of Gray Horse, Oklahoma , and guest speaker at banquet, is obscured in western Kansas dust cloud at far end of room.

FIG. 4.—Association executive committee at twentieth annual meeting, Wichita, Kansas, March 23. Outgoing committee, standing, left to right: Frank R. Clark, past-president; Edwin B. Hopkins, vice-president; Monroe G. Cheney, secretary-treasurer. Incoming committee, seated, left to right: William B. Heroy, past-president; A. Irving Levorsen, president; Frank A. Morgan, vice-president; Ernest C. Moncrief secretary-treasurer. Editor Luther C. Snider, of each committee, was not present.

We shall not forget the twentieth annual meeting. Twenty years! Not long. The men who gathered at the first banquet are still extending their contours and driving new stakes. Look at some of the founders in the photograph taken at Wichita, "20 years after." They and about 40 others, on January 7 and 8, 1916, in the geology lecture room on the third floor of the Science Building at the University of Oklahoma, made up the gathering which is recognized as the first annual meeting of the group of geologists of the Southwest which a year later became the Southwestern Association of Petroleum Geologists, and in 1918 became The American Association of Petroleum Geologists. Twenty years. Hardly long enough to map all the structures. There's more oil to be found and they're going back again with modern methods, ingenious instruments, and another generation of geologists.

Golf Tournament

The annual golf tournament was held at the Wichita Country Club, Friday afternoon. Twenty-nine members and 16 invited guests competed. One 18-hole match was played. The J. Wallace Bostick cup was won by Charles Newbold (guest), oil operator of Wichita, with a low gross score of 75. The member winner in the Bostick competition was George W. Snider of San Antonio, Texas, with a low gross score of 83. The name of each has been engraved on the Bostick trophy at Association headquarters in Tulsa. The local committee awarded additional prizes as follows.

Low Gross		*Gross*	*Handicap*	*Net*	*Prizes (Golf Balls)*
	George W. Snider (member)	83			Dozen
	Charles Newbold (guest)	75			Dozen
First Flight					
Low net	Theodore A. Link (member)	86	23	63	Half dozen
Best selected 9 holes	W. W. Coleman (guest)			31	Half dozen
Second Flight					
Low gross	Hastings Moore (guest)	81			Dozen
Low net	S. F. Harris (member)	85	18	67	Half dozen
Best selected 9 holes	Edwin A. Dawson (member)			33	Half dozen
Third Flight					
Low gross	E. I. Thompson (member)	90			Dozen
Low net	A. J. Montgomery (member)	96	28	68	Half dozen
Best selected 9 holes	M. T. Higgs (member)			39	Half dozen

Division of Paleontology and Mineralogy

The ninth annual meeting of the Society of Economic Paleontologists and Mineralogists was held on Friday and Saturday. The technical program included 20 papers. The officers for the year ending March, 1936, are: president, W. H. Twenhofel, Madison, Wisconsin; vice-president, U. S. Grant, IV, Los Angeles, California; secretary-treasurer, Gayle Scott, Fort Worth, Texas; editor, Raymond C. Moore, Lawrence, Kansas.

Division of Geophysics

The sixth annual meeting of the Society of Petroleum Geophysicists was held on Thursday and Friday. The technical program included 13 papers. The officers for the year ending March, 1936, are: president, B. B. Weatherby, Tulsa, Oklahoma; vice-president, L. W. Blau, Houston, Texas; secretary-

treasurer, Gerald H. Westby, Tulsa, Oklahoma; editor, F. M. Kannenstine, Houston, Texas.

Convention Registration

The total registration was 1,181, classified as follows: 1 honorary member, 457 members, 65 associates, 386 non-member men, and 272 non-member women.

Executive Committee

The executive committee of the Association, under whose general supervision the convention was arranged, were: William B. Heroy, chairman; Monroe G. Cheney, secretary; Frank Rinker Clark, Edwin B. Hopkins, and Luther C. Snider.

Kansas Geological Society

The officers of the Kansas Geological Society, the official host at the twentieth annual meeting, are: president, Howard S. Bryant, vice-president, James I. Daniels, secretary-treasurer, Ward R. Vickery.

Wichita Committee

The local committees on arrangements were the following.

General.—E. G. Moncrief, chairman; F. L. Aurin, E. L. Bradley, John L. Garlough.

Program.—W. A. Ver Wiebe, chairman; Anthony Folger, J. F. Kinkel, Jerry E. Upp, F. E. Wimbish.

Registration.—Marvin Lee, chairman; E. Gail Carpenter, Roy H. Hall, A. M. Meyer, R. A. Whortan.

Entertainment.—Howard S. Bryant, chairman; Lee H. Cornell, James I. Daniels, Walter W. Larsh, C. J. Stafford, E. A. Wyman.

Equipment.—J. P. McKee, chairman; W. R. Vickery, Glen C. Woolley.

Publicity.—L. R. Fortier, chairman; L. A. Crum, Edward A. Koester.

Trips.—L. W. Kesler, chairman; William L. Ainsworth, Garvin L. Taylor.

Golf.—Edwin N. Carlson, chairman; Edwin A. Dawson, L. I. Yeager.

Reception.—E. P. Philbrick, chairman; Phil K. Cochran, L. C. Morgan, W. B. Sinclair.

LADIES ENTERTAINMENT

In charge.—Walter W. Larsh.

General.—Mrs. John L. Garlough, Mrs. Fred G. Holl, Mrs. George H. Norton.

Reception.—Chairmen: Mrs. Walter W. Larsh, Mrs. Marvin Lee. Assisting: Mrs. E. L. Bradley, Mrs. W. K. Cadman, Mrs. Gail Carpenter, Mrs. Loren A. Crum, Mrs. Edward A. Koester, Mrs. R. B. Downing, Mrs. L. R. Fortier, Mrs. H. W. Hull, Mrs. J. F. Kinkel, Mrs. E. C. Moncrief, Mrs. F. E. Wimbish, Mrs. E. A. Wyman, Mrs. J. Z. Zimmerman.

Musicale and "get-acquainted" tea.—Chairmen: Mrs. L. C. Hay, Mrs. Roy H. Hall, Mrs. Louis A. Mylius. Assisting: Mrs. F. L. Aurin, Mrs. R. B. Downing, Mrs. Anthony Folger, Mrs. Fred G. Holl, Mrs. Edward A. Koester, Mrs. J. P. McKee, Mrs. Robt. B. McNeely, Mrs. L. C. Morgan, Mrs. Geo. H. Norton, Mrs. E. P. Philbrick, Mrs. Homer A. Scott, Mrs. R. A. Whortan.

Presiding at the tea tables: Mrs. Wm. L. Ainsworth, Mrs. Howard S. Bryant, Mrs. Phil K. Cochran, Mrs. John L. Garlough, Mrs. L. W. Kesler, Mrs. Walter W. Larsh, Mrs. Marvin Lee, Mrs. H. W. McLellan, Mrs. E. C. Moncrief, Mrs. E. A. Wyman.

Luncheon.—Chairmen: Mrs. Edwin A. Dawson, Mrs. L. C. Morgan. Assisting: Mrs. Richard Foley, Miss Olive Hoffman, Mrs. Perry R. Hanson, Miss Elizabeth Isaacs, Mrs. A. M. Meyer, Mrs. Lindsey G. Morgan, Mrs. E. S. Pratt, Mrs. A. S. Price, Mrs. Geo. D. Putnam, Mrs. B. S. Ridgeway, Mrs. W. B. Sinclair, Mrs. Garvin Taylor, Mrs. Jerry Upp, Mrs. W. R. Vickery, Mrs. H. R. Woodward, Mrs. E. A. Wyman, Mrs. L. I. Yeager.

Schedule of Events

The following schedule of events and the technical program are taken from the printed program distributed at the convention.

(All meetings and sessions in Ball Room or on Mezzanine, Allis Hotel, unless otherwise announced. Admission to technical sessions is free. Admission to all entertainment by ticket only.)

TUESDAY, MARCH 19 (PRE-CONVENTION)

7:00 P.M. Executive Committee, William B. Heroy, chairman

WEDNESDAY, MARCH 20 (PRE-CONVENTION)

Registration. Lounge

9:00 A.M. Committee on applications of geology, Frederic H. Lahee, chairman. Room 304, Mezzanine

9:00 A.M. Committee on geologic names and correlations, Ira H. Cram, chairman. Room 303, Mezzanine

9:00 A.M. Society Petroleum Geophysicists business committee, Room 301, Mezzanine

11:00 A.M. Business meeting, research committee, Donald C. Barton, chairman. Ingalls Room, Mezzanine

2:00 P.M. General business committee, Ed. W. Owen, chairman. Ingalls Room

6:30 P.M. Informal dinner, research committee, followed by round table discussion of "Cases of Migration or Non-Migration of Oil." Open to all Association members.

THURSDAY, MARCH 21 (CONVENTION)

7:30 A.M. Registration. Lounge

10:00 A.M. Address of welcome, response, and presidential address. Ball Room

10:45 A.M. General technical session. Ball Room

10:45 A.M. Annual business meeting, Society of Petroleum Geophysicists. Aviation Room, Mezzanine

1:45 P.M. General technical session—continued. Ball Room

1:45 P.M. Technical session, Society of Petroleum Geophysicists. Aviation Room, Mezzanine

3:00 P.M. Musicale by Dean Thurlow Lieurance, of Wichita University, at Innes Tea Room, followed by "get-acquainted" tea at 4:00 P.M.

4:45 P.M. Announcements, nomination of officers, appointment of committees. Ball Room

7:00 P.M. Sigma Gamma Epsilon dinner. Ball Room

FRIDAY, MARCH 22 (CONVENTION)

8:00 A.M. Ballot boxes open, Association booth. Lounge

9.00 A.M. General technical session—continued. Ball Room

9:00 A.M. Technical session, Society of Petroleum Geophysicists. Aviation Room, Mezzanine

12:30 P.M. College and fraternity luncheons.
Paleontologists' luncheon. Innes Tea Room
Geophysicists' luncheon. Lassen Hotel
1:00 P.M. Ladies' luncheon. Ball Room, Lassen Hotel
1:00 P.M. Golf tournament for Bostick Cup, Wichita Country Club
2.00 P.M. General technical session—continued. Ball Room
2:00 P.M. Technical session, Society of Economic Paleontologists and Mineralogists. Aviation Room, Mezzanine
4:00 P.M. Annual business meeting, Society of Economic Paleontologists and Mineralogists. Aviation Room, Mezzanine
7:30 P.M. Banquet and dance. Broadview Hotel

SATURDAY, MARCH 23 (CONVENTION)

9:00 A.M. Twentieth annual business meeting. Announcement of elections. Ball Room
10:00 A.M. Executive committees, joint meeting 1934 committee and 1935 committee
10:00 A.M. General technical session—continued. Ball Room
10:00 A.M. Technical session, Society of Economic Paleontologists andMineralogists. Aviation Room, Mezzanine
2:00 P.M. General technical session—concluded. Ball Room

SATURDAY, MARCH 23 (FIELD TRIP)

A.M. Salt mine at Lyons, electrically lighted.
Trip via oil fields, chiefly Burrton area

SUNDAY, MARCH 24 (FIELD TRIP)

A.M. Study of Permian and Pennsylvanian rocks of eastern Kansas under leadership of Raymond C. Moore, State geologist

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Technical Program

I. GENERAL ASSOCIATION PAPERS FOR ORAL PRESENTATION

1. Raymond C. Moore, Late Paleozoic Movements of the Earth's Crust
2. L. C. Morgan, Pre-Cambrian Studies in Central Kansas
3. Edward A. Koester, Geology of Central Kansas Uplift
4. Leo Fortier, Geology of Voshell Trend, Kansas
5. Virgil Kirkham, Origin of Folds in Michigan Basin
6. Fanny Carter Edson, St. Peter Stratigraphy
7. C. W. Tomlinson and Maynard P. White, Structure of Arbuckle and Ouachita Mountains
8. J. E. Adams, Upper Permian Stratigraphy of West Texas Permian Basin
9. Theodore A. Link, Some Types of Foothills Structures in Alberta, Canada
10. G. E. Condra and E. C. Reed, Pennsylvanian and Permian of Hartville Uplift, Wyoming
11. David White, Metamorphism of the Organic Sediments and the Derived Oils (Dr. White died February 7, 1935. Paper read by a substitute.)
12. Parker D. Trask, The Problem of Petroleum Generation
13. Norman L. Thomas, Contributions of Paleontology.
14. John Trenchard and J. B. Whisenant, Government Wells Oil Field Duv County, Texas
15. Symposium on Currently Active Fields
    Thornton Davis, South Texas
    Paul Weaver, South Texas Salt Dome
    Hal P. Bybee, West Texas
    M. M. Garrett, North-Central Texas
    Frank Gouin, Southwestern Oklahoma
    A. I. Levorsen, Franks Graben
    R. B. Newcombe, Michigan

North-Central Oklahoma
Roy Hall, Kansas

16. A. A. Baker, Geologic Structure of Southeastern Utah
17. Irving Perrine, Responsibilities of the Geologist in the Sale of Oil and Gas Securities to the Public
18. E. B. Noble and W. D. Kleinpell, Geology of Edison Oil Field, San Joaquin, Valley, California
19. Frederick G. Clapp, Safety of Water-Flooding Pressures at Bradford, Pennsylvania
20. Donald C. Barton, Variation and Migration of Crude Oil at Spindletop, Jefferson County, Texas
21. T. C. Hiestand, Regional Investigations, Oklahoma and Kansas
22. F. M. Van Tuyl and Ben H. Parker, Extra-Terrestrial Hydrocarbons and Petroleum Genesis
23. T. A. Hendricks, Carbon Ratios in a Part of the Arkansas-Oklahoma Coal Field
24. Henry Rogatz, Subsurface Geology of Texas Panhandle
25. Coleman D. Hunter, Natural Gas from Devonian Shale in Eastern Kentucky

II. GENERAL ASSOCIATION PAPERS FOR PRESENTATION BY TITLE

1. M. H. Billings and J. J. Maucini, Nacona Oil Field, Montague County, Texas
2. Frederick G. Clapp, Occurrence of Oil in Grabens
3. C. H. Dane, W. G. Pierce, and J. B. Reeside, Jr., Reconnaissance Observations of Upper Cretaceous Rocks North of Arkansas River in Eastern Colorado
4. James I. Daniels, "Hunton" Limestone in Kansas
5. D. Jerome Fisher, Western Lawrence County Oil Field, Illinois
6. D. Jerome Fisher, Origin of Petroleum with Particular Reference to the Deposits of the Western Lawrence County Oil Field
7. John L. Garlough and Garvin L. Taylor, Hugoton Gas Field, Kansas
8. Frank Gouin, Some Notes on Economic Spacing of Oil Wells
9. W. I. Ingham, Wellington Oil Field, Colorado
10. W. B. Lang, Permian Formations of Pecos Valley of New Mexico and Texas
11. George H. Norton, Upper Wellington and Lower Red-Bed Section in Kansas
12. O. C. Postley, Notes on Natural Gas Developments and Possibilities East of Main Oil and Gas Fields of Appalachian Region
13. Walter V. Searight, Recent Refinements in Lance Stratigraphy in South Dakota
14. E. I. Thompson, Notes on Stratigraphy of Central and Western Oklahoma
15. Lon B. Turk, Origin of Misener Sand and Relation of Its Local Characteristics to Oil and Gas Production
16. H. De Cizancourt, Research in French Colonies
17. Walter M. Small, Geology of Alpine Foreland in Upper Austria
18. M. T. Halbouty and F. W. Mueller, Geology and Geophysics of Southeast Flank of Jennings Field, Acadia Parish, Louisiana, with Special Reference to Overhang

III. PALEONTOLOGY AND MINERALOGY

1. R. W. Harris, Ostracodes of the Arbuckle Limestone of Oklahoma
2. Ira Higgins Cram, Faunal Zones in the Pre-Pennsylvanian of Oklahoma
3. Charles Ryniker, The Stock of Triticites ventricosus (Meek and Hayden)
4. Maynard P. White, Some Fusulinid Problems
5. R. C. Moore, Basis of Classification of Bryozoa
6. Betty Kellett Nadeau, Basis of Classification of Ostracodes
7. O. Hoffman, Nature and Distribution of the Hunton Formation in Kansas
8. Norman D. Newell, The Missouri-Virgin Boundary in Kansas
9. A. L. Lugn, Sediment Types
10. A. C. Tester, Studies on the Sediments of the Pennsylvanian of Iowa
11. E. C. Reed, Some Results of an Insoluble Residue Study of the Pennsylvanian of Nebraska
12. Quentin D. Singewald and Charles M. Reed, Insoluble Residues from Paleozoic Limestones of the Mosquito Range, Colorado
13. C. I. Alexander, Stratigraphy of the Midway (Eocene) of Southwest Arkansas and Northwest Louisiana

14. MARION SETZER, Additional Midway Microfossils from the Gulf Coast of the United States
15. M. M. KORNFELD, The Rôle of Diatoms in the Texas Tertiary Subsurface Stratigraphy
16. DAN J. JONES, Conodont Assemblages from the Nowata Shale
17. MAXIM K. ELIAS, Probable Depth of Deposition of Big Blue Sediments in Kansas
18. J. WILLIS STOVALL, W. S. STRAIN, J. B. WHARTON, J. TEAGUE SELF, Tertiary and Quaternary Proboscideans of Oklahoma
19. J. WILLIS STOVALL, Tertiary Horses at Optima, Oklahoma
20. HAROLD H. HAWKINS, A Calcareous Alga in Upper Pennsylvanian of Kansas

IV. GEOPHYSICS

1. JOHN W. FLUDE, Portable Storage Magazines for Dynamite and Caps
2. ROY HIGHTOWER, Premature Explosions in Seismic Explorations
3. G. H. LOVING and G. H. SMITH, Explosives and Electric Blasting Caps for Geophysical Prospecting
4. PAUL W. KLIPSCH, Performance of Oscillograph Amplifiers to Transient Shock Excitation
5. E. E. ROSAIRE, Strategy and Tactics in Geophysical Exploration for Petroleum
6. DONALD C. BARTON, Delimitation of Cap by Torsion Balance, Hoskins Mound, Brazoria County, Texas
7. PAUL WEAVER, Irregularities in Torsion-Balance Surveys from Near-Surface Effects
8. E. W. K. ANDRAU, Schlumberger Correlations and Tectonic Problems on Gulf Coast Salt Domes
9. MAURICE EWING, A. P. CRARY, and J. W. PEOPLES, Seismic Tests on Anthracite
10. C. A. HEILAND, Confirmation of Reflection Work in Canada by Drilling
11. GERALD H. WESTBY, Effect of Surface and Near-Surface Beds in Reflection Seismic Results
12. J. BRIAN EBY and ROBERT P. CLARK, Relation of Geophysics to Salt-Dome Structures
13. Symposium of Geophysical Activity Throughout the United States and Some Foreign Countries

    G. H. WESTBY, HENRY SALVATORI, JOSEPH L. ADLER, H. B. PEACOCK, JOHN H. WILSON, E. G. LEONARDON, O. C. LESTER, JR.

PRESIDENTIAL ADDRESS

WILLIAM B. HEROY

This Association has on only one occasion participated as an organization in a survey of the extent of the petroleum reserves of the United States. In 1922, a committee appointed by President Wallace Pratt collaborated with members of the United States Geological Survey in preparing an estimate of recoverable oil as of December 31, 1921, which was published in the *Bulletin*.

The subject has not been discussed at any subsequent meeting of the Association and this fact, together with the present considerable interest in the topic, constitutes such justification as I have for bringing it to your attention. It will be understood, I am sure, that the opinions which I express are purely personal and are not to be considered as stating officially the viewpoint of this Association.

Public interest in the extent, conservation, and utilization of the natural resources of the United States has been by no means constant. During some periods of our recent history this entire field of our national economy has been subjected to intense illumination and equally searching investigation, with much longer intervening periods of relative obscurity and inattention on the part of the public generally. The periods of greatest interest were from 1907

to 1909, from 1922 to 1925, and during the last two years. The first of these periods coincided with the recovery from the financial stringency of 1907; the second period came shortly after the post-war depression of 1920; and the present period of interest closely follows the low point of the current major economic disturbance. A sequential relationship between periods of financial and economic stringency and periods of active public interest in the conservation and use of natural resources seems thus to be indicated. A suffering public, exasperated by privation, searches for the cause of its ills, both to find relief from its immediate burdens and in the hope of preventing a repetition of its trying experiences. Concentration of ownership and the wasteful use of exhaustible natural resources are envisaged as among the chief causes of depression and, in consequence, demands for investigation and for corrective legislation become insistent.

Certainly there can be no question of the present interest of the Federal Government in those questions which have come to be grouped under the general term "conservation," and of its specific attention to the subject of mineral resources. In its recently issued report[1] the National Resources Board expresses the belief "that mineral reserves are vested with a public interest which justifies extension of public supervision to those specific conditions affecting our mineral industries, which are distinctly detrimental both to the public and to the industries themselves, and which seem to be beyond the power of the industries themselves to remedy." Speaking more specifically of the reserves of oil and gas the report further states[2] that

> Proved reserves never have been sufficient to supply our domestic needs for more than a decade or two, and because of the highly conjectural nature of estimates of the magnitude of unproved reserves, fears of an imminent shortage have arisen repeatedly. . . . New production to postpone the day of shortage will no doubt be found, but sooner or later the Nation's output of oil from wells will be insufficient to meet the demand.

Whatever our individual opinions may be as to the accuracy of findings of such Federal agencies and as to the control that the Federal Government may properly exercise over the development of petroleum resources, few will question that the administration now in power is pursuing a policy which leads directly toward a larger measure of control by the Federal Government over minerals and particularly petroleum.

In the working out of such a policy one of the first questions to arise concerns the quantity of any particular mineral substance which the nation has at its disposal. Obviously no great public apprehension can be aroused with reference to the future supply of any mineral, for example, such as coal, which is so widely distributed and is found in such quantities that the life of our deposits can, by no reasonable method, be estimated in smaller units than centuries. The case of petroleum is, however, different. Not only is there an enormous and increasing demand for petroleum products from every branch of transportation and industry, but it constitutes one of the corner stones of our structure of national defense. Out of any discussion of the

[1] National Resources Board, "A Report on National Planning and Public Works in relation to Natural Resources and including Land Uses and Water Resources with Findings and Recommendations: Part IV, Report of the Planning Committee for Mineral Policy," p. 393. Government Printing Office, Washington, D.C., 1934.

[2] Ibid., p. 405.

conservation of petroleum there immediately arises a demand for an appraisal of the quantity of this resource upon which the country may depend for its future needs.

It has become established usage to refer to such supplies of petroleum as still remain beneath the surface, whether discovered or undiscovered, as "petroleum reserves." Ordinarily the word "reserve" implies a supply of something withheld for future use; a planned and conscious segregation against a possible or definite future requirement. Most of our so-called "petroleum reserves" are not, in that sense, reserves at all. A very small part of our petroleum resources lies within the boundaries of public-land reservations created by the government. Some of the larger companies, also, have retarded the development of areas exclusively under their control so that they might count on some oil for the morrow. In certain flush fields, governmental action has limited the amount of oil which might be taken from a well in a particular time. Such restriction or proration does, for the time being, create what Pogue[3] has termed an "underground inventory," and tends to build up temporarily a reserve of known but unproduced oil.

For the most part, however, our underground supplies of petroleum are "reserves," in the sense of the present special usage of that term, only because of the operation of such influences as the following:

1. They have, up to this time, escaped discovery, in spite of the ingenuity of the geologist and the skill of the driller.
2. The time since discovery has been insufficient for the extraction of all the oil at the rate at which the sand will yield its production.
3. The price of oil has been too low to repay the producer for the labor required to bring the oil to the surface and send it to market.
4. The technical problem of its recovery, within the existing price structure, has not been satisfactorily solved.

If the total original oil content of the United States were to be represented (Figure 1) by a cube of indefinite dimensions, a part of the cube, marked in the diagram by the letter *A*, may indicate the total amount of petroleum actually brought to the surface up to the present time. From year to year, as production continues, that block will be enlarged and will take in more and more of the cube. This enlargement may take place by increments in three different directions. It may be enlarged by production of oil by methods now commonly used from the reserves of fields now discovered and producing, encroaching upon that part of the cube marked by the letter *B*. Second, it may be enlarged by the discovery of new fields and of deeper horizons in present producing areas, thus taking in a part of the block that is marked *C*. Third, oil production may be augmented by greater recovery, both from fields now producing and from future fields, extending into that part of the cube at the rear, marked *D*.

Reserves of petroleum thus fall into three categories:

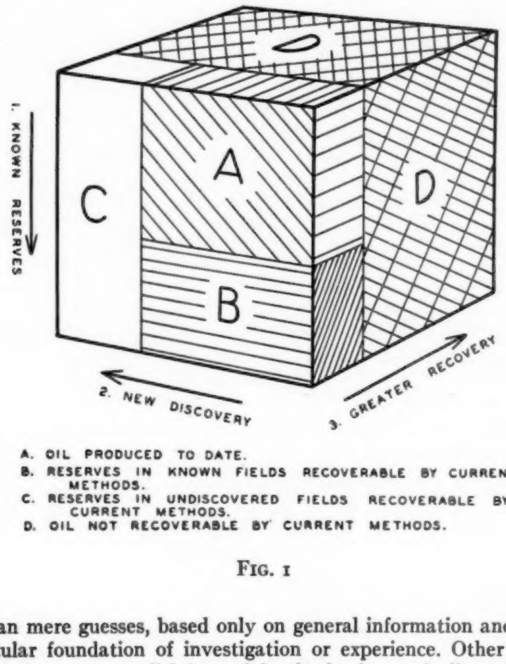
Class 1. Reserves proven to exist and capable of being produced over a period of years by methods in current use;

[3] Joseph E. Pogue, "Economics of the Crude Oil Potential in the United States," *Trans. Amer. Inst. Min. Met. Eng. Petrol. Dev. and Tech.*, Vol. 92 (1931), pp. 633–40. *Ibid.*, "Economics of Proration," Vol. 98 (1932) pp. 69–76.

Class 2. Reserves undiscovered but which may reasonably be expected to be found in deeper sands and untested areas;
Class 3. Reserves not recoverable by operating methods now in common use, and which will become available only as a result of the application of methods which are now either experimental or entirely undeveloped.

Throughout the last thirty years many statements as to the extent of the Nation's oil resources have been issued. Some of these have been little

RELATION OF PETROLEUM RESERVES



A. OIL PRODUCED TO DATE.
B. RESERVES IN KNOWN FIELDS RECOVERABLE BY CURRENT METHODS.
C. RESERVES IN UNDISCOVERED FIELDS RECOVERABLE BY CURRENT METHODS.
D. OIL NOT RECOVERABLE BY CURRENT METHODS.

FIG. 1

better than mere guesses, based only on general information and resting on no particular foundation of investigation or experience. Other statements have come from men well informed in the business of oil production and whose opinions are entitled to respect, but whose conclusions are based on broad experience rather than on detailed consideration. Only three or four statements concerning the petroleum reserves of the United States have been based on comprehensive surveys of the various producing regions and a consideration of the probable future production of individual fields. The figures resulting from such surveys are entitled, in the opinion of the writer, to rank as estimates. It must be recognized that some of the guesses may, in the long run, turn out to be closer approximations than some of the more carefully prepared estimates. However, those of us who are accustomed to attacking such problems along scientific lines will naturally give greater credence to the results of the detailed surveys and analyses.

The second diagram (Figure 2,) compares the figures given in the more authoritative estimates of our petroleum reserves made in the last thirty years. In each case the estimate has been assigned to one of the three classes just defined. Some of the estimates of Class 1 include only future production from known fields. Others include past production as well, and endeavor to appraise the original oil content. The diagram also shows the cumulated petroleum production of the United States, reaching a total of 16,600,000,000 barrels at the close of 1934.

From these various estimates two have been selected for more detailed

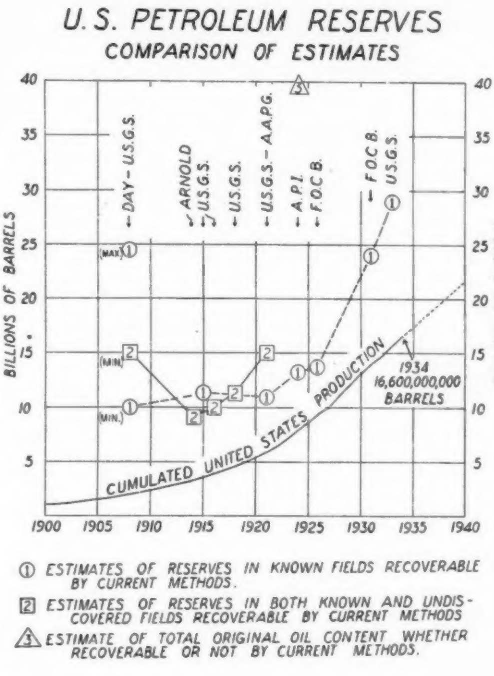


FIG. 2

consideration, the American Petroleum Institute estimate of 1925 and the United States Geological Survey estimate of 1934.

Taking, first, the American Petroleum Institute estimate, the third diagram (Figure 3) is an attempt to visualize the conclusions of that survey. As of the beginning of 1925 total production of the United States had reached nearly eight billion barrels. Reserves of known fields were estimated at over five billion barrels. Oil which would be left in the ground in these known fields after pumping ceased was estimated at 26 billion barrels. Oil in undis-

covered fields was not estimated. The opinion was, however, expressed that the rate of discovery of new fields had not in 1925 reached its maximum and one is left with the impression that the Committee which prepared the report thought that discoveries in the future would equal in quantity those made in the past. The diagram has accordingly been drawn to show oil in undiscovered fields as about equal in volume to that in discovered fields. On that basis the total original oil resources of the United States would be of the order of 80 billion barrels.

A similar diagram (Figure 4) has been prepared to illustrate the 1934 estimate of the United States Geological Survey, with modifications to bring it down to the end of that year. Over the decade which had intervened between 1924 and 1934 total United States production had increased to over

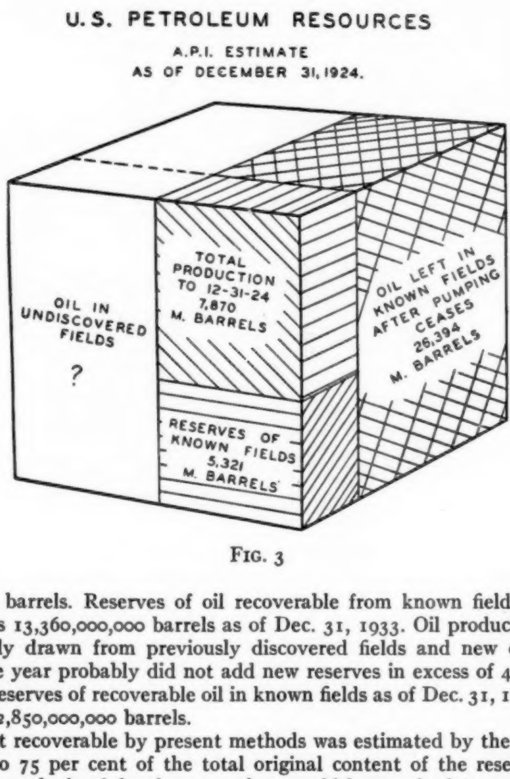


FIG. 3

16 billion barrels. Reserves of oil recoverable from known fields were estimated as 13,360,000,000 barrels as of Dec. 31, 1933. Oil produced in 1934 was largely drawn from previously discovered fields and new discoveries during the year probably did not add new reserves in excess of 400,000,000 barrels. Reserves of recoverable oil in known fields as of Dec. 31, 1934, would then be 12,850,000,000 barrels.

Oil not recoverable by present methods was estimated by the Survey at from 65 to 75 per cent of the total original content of the reservoir. The change in methods of development that would be required to make this oil available and the consequent increase in cost of production were thought to take this unrecovered oil out of the class of commercial reserves because "it cannot be produced at the surface under existing conditions." The amount

of this oil, unrecoverable by present methods, would, on the basis stated, be about 70 billion barrels.

With reference to oil in undiscovered fields no estimate was made by the Survey. It was stated, however, that the number of fields to be found in the future would apparently be less than the number found in the past. If, for purposes of comparison, it is assumed that the total oil remaining to be discovered is half as much as that already found, another 15 billion barrels recoverable by present methods awaits discovery. And, if oil not recoverable by present methods is taken into consideration, the total original oil content of the United States reaches the figure of 150 billion barrels.

A comparison of these two estimates reveals that, over a period of ten years, estimates of original resources of recoverable oil have been more than

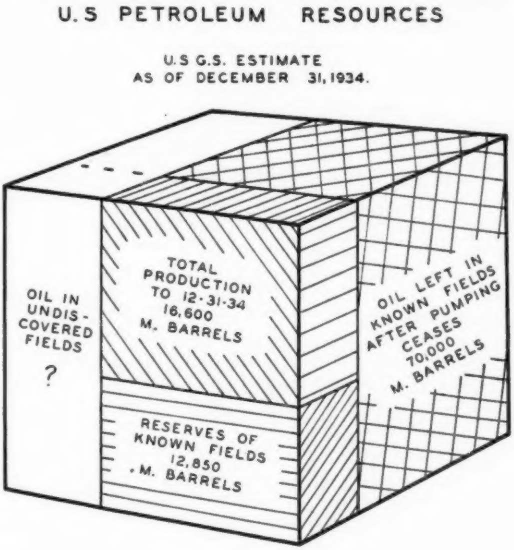


FIG. 4

doubled, 13 billions in 1925, 30 billions now. Assuming the two estimates to be of equal accuracy it follows that in the same decade 17 billion barrels of recoverable petroleum were added to reserves while production during the same period was almost 9 million barrels.

Most of this increase in reserves is due to the discovery of new fields, rather than to increases of estimates of the content of previously discovered fields, or to increased recovery postulated to result from technical advances. The only state for which estimates of reserves have been definitely increased because of improvements in methods of recovery is Pennsylvania, where an increase in reserves of 160,000,000 barrels is doubtless due to the effect that water drive is expected to have on future production. Figures for some of the other states may also have been increased somewhat to allow for the

effect of repressuring but, on the whole, the portion of the increase in figures of recoverable reserves that results from the assumption that recovery methods will be more efficient in the future is very small. Half a billion barrels would undoubtedly cover all of the reserves added to the estimates to take care of more efficient future recovery.

During the last ten years the United States has produced nearly nine billion barrels of oil. Of that total about 40 per cent has been produced from fields that were producing prior to Dec. 31, 1924, whereas about 60 per cent has been obtained from fields discovered since that date. About two-thirds of the reserves of recoverable oil estimated to exist at that time have since been actually produced. The figure of 17 billion barrels of recoverable oil discovered in the last decade may then be broken down as follows:

Oil produced, 1925-1934, inclusive	5,500,000,000 barrels
Reserves created by new discoveries	11,000,000,000 "
Reserves resulting from better methods of recovery	500,000,000 "

Making every allowance for inaccuracy in the above figures it seems beyond doubt that the increase in known reserves of recoverable oil has been due almost entirely to the discovery of new fields.

I feel certain that many of you who have been listening to this tedious presentation of statistical data feel that entirely too much dependence is being placed on figures of this character; that the probabilities of major errors in the estimates are so great that little if any dependence can be placed upon conclusions derived from them. The speaker has been one of those who, in the past, has expressed the most serious doubts as to the practical value of estimates of our national petroleum reserves, made, as they have been, under pressure and against time, for the purpose of furnishing categorical answers to Congressional resolutions or other similar demands. The result has been, all too frequently, a summation of hastily prepared guesses. With all their defects, the estimates, especially more recent ones, are of material assistance in helping us to form some conception of the extent and character of our oil resources.

The duty of making such estimates has generally been assigned to petroleum geologists on the basis that their professional training and experience gives them an intimate knowledge of the various elements entering into the problem. The reputations and professional pride of the men engaged in this work have naturally been powerful incentives to induce them to use the best available information and to compile it with care. When subsequent developments have shown that the estimates were not highly accurate and could not be taken too literally, geologists have naturally been compelled to accept the criticism that has been aimed at the estimators when discrepancies were disclosed as a result of later discoveries and development. It has been not uncommon for critics to take estimates of recoverable oil, made ten to twenty years ago, which were clearly stated to include only then known fields, and misrepresent the estimates as having been those of the total oil resources of the country in both known and undiscovered fields. Having thus distorted the facts they point out with satisfaction that subsequent production has far exceeded these early estimates, ignoring the fact that most of the subsequent production has come from fields not known or taken into account when the estimate was made. It should be made very clear that the oil supply of fields discovered more than ten years ago has been largely exhausted and

that the present requirements of the industry for crude oil are being supplied chiefly from more recently discovered fields.

With the continued testing of the remaining wildcat territory and the increased difficulty of finding new pools the question as to how much oil remains in the ground will become more and more acute. Instead of occasional demands for estimates of petroleum reserves in periods of fear of shortage, the industry, the government, and the public will soon expect annually revised statements of our petroleum resources. These will take into account not only producing fields but also prospective areas and will consider all new discoveries and all newly gained experience as to how much oil can be recovered. Close and constant study of the problem will gradually increase the accuracy of the basic data and the results will in consequence become more dependable. I have reluctantly come to believe that the work of preparing such estimates and of making them as reliable as possible must be squarely accepted as one of the obligations of our profession.

MINUTES, TWENTIETH ANNUAL BUSINESS MEETING ALLIS HOTEL, WICHITA, KANSAS, MARCH 21 AND 23, 1935

WILLIAM B. HEROY, *presiding*

The meeting was called to order at 4.45 P.M., March 21, 1935, by William B. Heroy, president, Monroe G. Cheney serving as secretary.

1. *Election of honorary members.*—The election of Gilbert D. Harris, professor emeritus of Cornell University, and W. C. Mendenhall, director of the United States Geological Survey, to honorary membership in the Association was announced by president Heroy.

2. *Nominations of officers.*—The president called for nominations of officers of the Association for the ensuing year. The following nominations were made.

For president:	A. IRVING LEVORSEN, nominated by Ira H. Cram
For vice-president:	FRANK A. MORGAN, nominated by W. E. Wrather
For secretary-treasurer:	E. C. MONCRIEF, nominated by Harold W. Hoots
For editor:	LUTHER C. SNIDER, nominated by E. DeGolyer

There being only one nominee for each office, motion was made, seconded, and carried in each case that the secretary be authorized to cast a unanimous vote for each nominee.

3. *Resolutions committee.*—Hugh D. Miser, chairman, S. H. Gester, and Gayle Scott were appointed by the president as a committee on resolutions.

The meeting was recessed at 5:00 P.M. until 9:00 A.M., March 23, 1935.

The recessed meeting was called to order at 9:30 A.M., March 23, 1935, by William B. Heroy, president.

4. *Reading of minutes.*—It was moved, seconded, and carried that the reading of the minutes of the annual meeting held at Dallas, Texas, March 22–24, 1934, be dispensed with, inasmuch as they had been published in the *Bulletin.*

5. *Report of officers.*—The reports of president William B. Heroy, secretary-treasurer Monroe G. Cheney and editor L. C. Snider were read (Exhibits I, II, and III).

6. *Report of general business committee.*—The report of the general business committee (Exhibit IV) was made by the secretary, Monroe G. Cheney. Motion was made, seconded, and carried that this report and recommendations therein contained be accepted and approved. Upon motion made, seconded, and adopted, the following committee reports read before the general business committee were accepted for publication in the May issue of the *Bulletin* without being read at the annual business meeting: committee on geologic names and correlations, Ira H. Cram, chairman; research committee, Donald C. Barton, chairman; applications of geology, F. H. Lahee, chairman. These reports appear as Exhibits V, VI, and VII, respectively.

7. *Change of by-laws: dues.*—Motion made by D. C. Barton was seconded and carried unanimously approving change of by-laws as to the first two sentences of Article I, Section 2, to read as follows, effective as of January 1, 1935.

The annual dues of members of the Association shall be ten dollars ($10.00).The annual dues of associates for not to exceed three years after election shall be six dollars ($6.00); for the second three-year period eight dollars ($8.00); thereafter, the annual dues of such associates shall be ten dollars ($10.00).

8. *Change of by-laws: reinstatement.*—Motion was made, seconded, and unanimously adopted that the following paragraph be added to Article II, Section 4, of the by-laws.

In the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for non-payment of dues and who shall apply for reinstatement, the executive committee is authorized, in its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency, provided the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the executive committee. Such member or associate shall not be entitled to receive the *Bulletin* for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

9. *Application for affiliation.*—The application of the Dallas Petroleum Geologists to become an affiliated society of the Association was submitted to the meeting by the president with explanation that the executive committee, with legal advice, had approved this affiliation subject to the affirmative vote of two-thirds of the membership present and voting at the annual meeting. Motion was made, seconded, and adopted unanimously that this affiliation be approved.

10. *Vote of thanks.*—Motion made by Alexander Deussen was seconded and carried, extending a vote of thanks, for services rendered, to the three retiring members of the executive committee: past-president Frank R. Clark, vice-president Edwin B. Hopkins, and secretary-treasurer Monroe G. Cheney.

11. *Report of resolutions committee.*—The report of the resolutions committee (Exhibit VIII), presented by Hugh D. Miser, was adopted unanimously.

12. *Introduction of new officers.*—The newly elected officers of the Association were introduced by the retiring president.

Upon motion meeting was adjourned at 10.45 A.M.

WILLIAM B. HEROY, *president* MONROE G. CHENEY, *secretary*

EXHIBIT I. REPORT OF THE PRESIDENT

(Year Ending March 23, 1935)

In presenting this report on the work of the Association for the year now closing I shall refer chiefly to those activities which are of a more general character, leaving to the treasurer, Mr. Cheney, and the editor, Dr. Snider, a more detailed presentation of the accomplishments in their respective departments. On this occasion I wish to record formally my sense of deep personal gratitude for the honor which the Association has conferred in entrusting me with its leadership during the past year.

Such achievements as this report may bring to your notice are the result of the loyal and energetic coöperation of our entire organization. The executive and other committees, the headquarters staff, and the membership in general have shown an unfailing interest in the work of the Association and I wish to express my personal appreciation to all who have helped to make the year a successful one.

Executive committee.—Because the members of the executive committee have been geographically quite widely separated this year, more matters have been considered by correspondence and a smaller number of formal meetings have been held than in previous years. Four meetings, two in Dallas, one in New York, and one in Wichita, have been attended by three or more members of the committee.

Membership.—A healthy condition of membership is fundamental to the progress of this organization. We have no more important problem than that of associating with us properly qualified members of our profession, and, once having admitted them, of doing all that is reasonable and fair to hold them on the membership rolls.

During the year 1934–1935, 42 members and 34 associates have been elected to and have accepted membership, a total, including one honorary member, of 77 members added. However, these increases have not compensated for losses. Through death, resignation, and separation because of non-payment of dues, we have lost 174 members. We have 70 less members enrolled than a year ago. While this loss is deeply regretted, the present situation is more favorable than these figures indicate. Last year on March 1, 1052 members and associates, more than half our membership, were in arrears as to payment of dues. This year only 740 members and associates, 37 per cent, were in arrears; more members are paying their dues promptly this year than last.

During the year the president undertook a detailed survey of employment in the Association. This survey has been only partially successful, owing to the lack of returns from some of the larger districts. It indicates, however, that there has been a definite increase in employment among our members and that the number of cases of distress has been lessened. The survey included not only our present membership, but, so far as possible, those members who had resigned or been dropped during the last two years. A considerable number of those who had been thus separated had established themselves in other occupations or were engaged in other branches of the oil industry not closely connected with geology.

The district organizations and local affiliated societies have accomplished a great deal of effective work, both in relieving definite distress and in finding employment. Experience has shown that these activities can be carried on

more effectively through such local agencies than through the national organization, which is generally unable to obtain information with promptness concerning vacancies.

The problem of building up our membership is thus threefold:

1. That of making it possible for younger men entering the profession to become associated with us without too great financial burden;

2. That of bringing back into the organization members who, through financial or other reasons, have failed to keep up their memberships;

3. That of keeping our present membership interested in the work of the Association through timely publication of geological information.

Concrete proposals which will have a bearing on these questions will come before you for consideration at this meeting.

Death has claimed this year 10 members and 1 associate, among them Dr. David White, an honorary member of the Association.

Finances.—As will be fully established by the treasurer's report, the year has been one of very satisfactory accomplishment financially. A net operating profit of $5,060 has been achieved. The reduction of 20 per cent in the amount of the annual dues was made without unfortunate effects on our finances, and has undoubtedly resulted in more members making payment and in more prompt collections.

At the present time the Association is financially in a position not only to print all the material that the editor considers suitable for inclusion in the *Bulletin*, but could substantially increase its size were desirable material contributed. The special volumes have been financed without the necessity of disposing of any securities. The Association has not lacked money for any activity which, in the opinion of the executive committee, would advance the interests of our membership.

Bulletin.—Under the guidance of Dr. Snider and the associate editors the *Bulletin* has maintained the high standard of technical excellence set by previous volumes. The headquarters editorial staff has kept its pages remarkably free from typographical errors. The committee on geologic names and correlations has assisted the editor by scrutinizing the usage of stratigraphic terms. In volume of material published, the 1934 *Bulletin* exceeds all earlier years, totaling 1,959 pages, of which 1,366 pages were devoted to major articles.

Special publications.—The outstanding event of the year is the publication of the volume *Problems of Petroleum Geology*, edited by W. E. Wrather and F. H. Lahee. The volume is dedicated to Sidney Powers, and is a fitting tribute to his memory and to his contributions to the progress of this Association. Its contents represent the best thought of our membership on many topics connected with the origin, accumulation and distribution of petroleum and it is an invaluable addition to the literature of our profession. I wish to record, on behalf of the Association, the appreciation that is due the editors and contributors to this volume, not only for the many hours of painstaking labor put into its preparation, but for the excellence of the technical material which has been included. It is a volume of 1,073 pages, well printed and bound. Out of an edition of 2,000 copies, 1,073 copies had been disposed of at the end of 1934.

The *Geology of Natural Gas*, under the editorship of Henry Ley, has

made notable progress during the year and will be the next publication in our series to appear. Most of it is now in page proof and it will probably go to the press about July 1. It will be our largest book, about 1,200 pages.

Work on the volume on the *Gulf Coast*, under the editorship of Donald C. Barton and George Sawtelle, has been progressing during the year. A large number of papers are now in the hands of the editors and, as soon as the work of producing the Natural Gas volume is completed, our headquarters staff will commence work on the Gulf Coast volume.

John M. Muir was authorized by the executive committee to complete as a publication of the Association a volume on the *Geology of the Tampico Embayment*, a work which had been in preparation for some time and for which many excellent maps were already available. Mr. Muir has made two trips to Mexico to obtain additional material and the manuscript is well advanced. It is hoped that this contribution, the result of a lifetime of experience in the area and of information gathered from many reliable sources, will be made available toward the end of this year.

Other projects in this field are a volume on the *Geology of Southwest Texas*, which is being sponsored by the San Antonio Section, and one on the *Oil Fields of California*, by the Pacific Section. Dr. Ralph D. Reed has undertaken the work of preparing the framework of the latter volume, which will contain, not only descriptions of the various fields, but much new material on the structural features of California and the distribution of oil-bearing horizons.

The committee on geologic names and correlations is undertaking the preparation of a *Glossary of Structural Terms Used in Petroleum Geology*, which, if completed along the lines now proposed, will be a most valuable contribution to systematic nomenclature.

Finance committee.—The increased responsibility for safe investment of the funds of the Association which rests on our financial organization has been shared with the treasurer by an able finance committee, consisting of W. E. Wrather, Joseph E. Pogue, and E. L. DeGolyer. Their efforts and sound advice have contributed in a large degree to the fact that our financial losses over the last few years have been very small. Our investments appreciated in value over $4,700 during the last year, and are now appraised at $48,179, of which $33,742 is in the General Fund, $13,251 in the Publication Fund, and $1,185 in the Research Fund.

Committee on geologic names and correlations.—This committee was created for the purpose of providing within the Association a technical board of review to consider questions of nomenclature and usage of geologic terms. It has functioned during the past year most efficiently under the chairmanship of Ira H. Cram. Its particular work has been the review of papers presented for publication in the *Bulletin*. The committee has, during the year, put into definite form its plans for the preparation of a *Glossary of Structural Terms Used in Petroleum Geology*, and work on the text will be commenced during the coming year.

Regional sections.—The Association has three organized regional groups of members, the Pacific, San Antonio, and Maracaibo sections. Each of these sections has been active during the year in holding meetings. The Pacific section held its annual meeting in Los Angeles, November 8–9, 1934. An excellent program of thirteen papers was presented. The San Antonio section

held its annual meeting, November 2–5. The technical sessions were held in Laredo and were followed by a field trip through southwest Texas into northern Mexico, occupying three days. The membership of the Maracaibo section and of the South American district has been substantially increased during the past year, in large measure because of the energy of P. E. Nolan, district representative.

Division of paleontology and mineralogy.—The Society of Economic Paleontologists and Mineralogists, a division of the Association, reports a year of considerable achievement. The Society entered into an agreement with the Paleontological Society of America whereby the latter will join in the publication of the *Journal of Paleontology*. The issues for 1935 will be increased to eight, each society being responsible for four issues. This coöperative arrangement, which has the approval and support of the Geological Society of America and of this Association, promises to meet fully the need for a single comprehensive journal in this field. The membership of the division is 248.

Division of geophysics.—This division, organized as the Society of Petroleum Geophysicists, has a membership of 174. It has been responsible for the preparation of material for the geophysical number of the *Bulletin*. With the growth of interest in geophysics the division contemplates the establishment of a publication devoted exclusively to articles dealing with geophysical subjects and especially to the application of geophysics to petroleum geology.

Research committee.—This committee under the chairmanship of D. C. Barton has functioned chiefly as a medium for the exchange of information and the discussion of problems. Outstanding activities were a joint meeting on May 19, 1934, with the research committee of the American Petroleum Institute for discussion of "Geological Changes in Petroleum Reservoirs Affecting Recovery," and a discussion of the topic, "Causes of Migration or Nonmigration of Oil," at the round table following the annual dinner of the committee on March 20, 1935. A series of papers bearing on this problem is proposed for publication in the *Bulletin*. F. B. Plummer is engaged in a census of research problems upon which members of the Association are engaged.

Committee on applications of geology.—Under the chairmanship of F. H. Lahee this committee has continued its most useful activities. Organized, to quote Dr. Lahee's words, "to explain how geology can be made to serve the public, and particularly how the petroleum industry may be served by this science," the committee has completed its third year of service. Substantial progress has been made in having geology and physiography taught in secondary schools. Local exhibits of geological material of general interest to the public have been sponsored in several districts. A number of our members have given public addresses of a popular character.

Carey Croneis reports that the second year of the exhibit on petroleum geology at "A Century of Progress" was fully as successful as the first. Approximately 500,000 school children, under teacher guidance, visited the exhibit.

Under a coöperative arrangement between the National Parks Service, of which Earl A. Trager is chief naturalist, and the University of Chicago, a

series of motion pictures, illustrative of geologic features and processes, is being produced for exhibition.

The value to the Association of frequent contact between the members of the executive committee and the local sections and districts has been amply established during past administrations. The geographic distribution of the officers during the past year has made this ideal somewhat difficult of accomplishment but there have been few local units which have not been visited during the year by one of the executive committee.

Attendance at the meeting of the production division of the American Petroleum Institute in May and the immediately following meeting of the Pennsylvania Field Conference gave opportunity for the president to meet many members in the Appalachian district.

In November the president attended the meeting of the Pacific section in Los Angeles. On the outbound trip he spent an evening in Denver with the members of the Rocky Mountain district. On returning from Los Angeles he attended the meeting of the American Petroleum Institute in Dallas, and a meeting of the executive committee was conveniently held at that time. Following the meeting of the Institute the San Antonio section and Tulsa geological societies were visited at enjoyable luncheon sessions. In company with the past president and the business manager the trip was extended to Wichita to make arrangements for the annual meeting and to meet the local committees. The Ponca City geologists entertained the party at dinner on November 22. The next day was spent in Wichita, where the party were the guests of the local geologists at luncheon. The entire trip occupied over three weeks.

A cordial invitation to attend the annual meeting of the San Antonio section was received. However, it was scheduled a week before the meeting of the Pacific section and it is greatly regretted that it was not possible to commence the trip early enough to attend both meetings.

The many courtesies and cordial hospitality extended by members of the Association during these visits are gratefully acknowledged. While extended officially to the president of the Association, they have been a great personal pleasure and constitute the most lasting memory of this eventful year. It has sometimes been said that services to organizations such as ours are not adequately appreciated, but the writer feels that all the effort which has been required to fulfil the duties of his office has been more than repaid in the satisfaction that comes from progress made and the enrichment of life that results from the making and renewing of friendships. I bespeak for the new officers the same cordial support which you have given to this administration.

WILLIAM B. HEROY, *president*

EXHIBIT II. REPORT OF SECRETARY-TREASURER

(Year Ending March 23, 1935)

The Association has had a favorable year as judged by increases in the number of new members, reinstatements, members in good standing, and a large net profit.

MEMBERSHIP

We shall miss the presence but retain the influence of the following mem-

bers of the Association who have died during the past year: Alex M. Alexander, Frank Carney, Charles L. Dake, Josef Th. Erb, William A. P. Graham, Thomas K. Harnsberger, Edwin S. Harris, Wallace G. Matteson, D. Bruce Seymour, Edwin M. Shepard, and one of our first honorary members, David White.

In spite of a decrease of 70 in our total membership, the underlying trend is definitely toward recovery. New members (77) plus reinstatements (103) were four times greater than two years ago, and nearly three times greater than last year. Members in good standing on March first during the past two years have increased from 875 to 991, and to 1,049. Membership applications from those not heretofore on our rolls total 50, as against 34 one year ago. Figure 1 has been prepared to aid in visualizing these trends and to show the

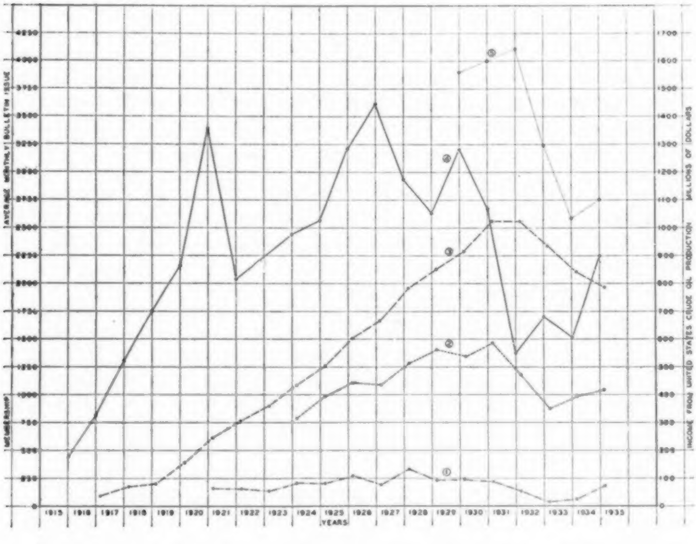


FIG. 1.—1. Total number of new members, new associates, and reinstatements for year ending March 1.
2. Total number of members and associates, in good standing, March 1.
3. Total number of members and associates, March 1.
4. Annual income from crude oil produced in United States (*Oil Weekly*, January 28, 1935).
5. Average number of copies of *Bulletin* printed each month.

close relation of membership trends of the Association to the income from crude oil produced in the United States. The average monthly issue of the *Bulletin* is also charted. It appears that the number of *Bulletins* printed during past years has been affected by prevailing tendencies toward over-optimism and extreme pessimism. Perhaps the oil income curve will serve as a

fairly reliable guide in predicting membership trends and *Bulletin* requirements in future years.

The average loss of membership during normal years appears to be about 60 per year. On this basis the Association membership has suffered excess losses of about 750 since 1931. It seems probable that at least 400 of these will seek reinstatement, and that within a few years our membership will regain its former peak. No doubt the Association will seek and welcome the reinstatement of former members who have helped to build it. The accompanying tables (I, II, and III) set forth certain data regarding membership of the Association.

EXECUTIVE COMMITTEE

During the past year the executive committee held meetings on March 24, November 15, January 7, and March 19. Certain important resolutions not heretofore reported in the *Bulletin* are listed herewith.

Bulletin.—2,700 copies per month were ordered for the months of April to July, 2,800 for August to December, and 3,000 for January to March, inclusive.

Additional 250 copies of the January, 1934, and 200 copies of the March, 1934, issues were authorized, to be reproduced by some suitable process.

Seventy-five bound volumes of the 1932 *Bulletin* were reserved for distribution to delinquent members who are reinstated, in case the number reinstated is greater than available supply of separately bound monthly numbers. Also unbound copies of the last 7 numbers of 1932, the last 9 numbers of 1933, and the bound copies of 1933 *Bulletins* were reserved for delinquent members and associates who become reinstated, after first setting aside the usual 25 copies (total bound and unbound) for sale with complete sets of the *Bulletin* in keeping with resolution of the executive committee of January 2, 1931, regarding "Near-Rare Bulletins."

Problems of Petroleum Geology.—The issue of this publication was set at 2,043. This decision was based on the number of advance orders and current membership in the Association. Also, the theoretical nature of the contents suggested that revised editions may be in order every few years. Four copies were ordered bound in leather for presentation to the parents, wife, and children of Sidney Powers. Three copies were given to each editor, and 35 reprints of each contribution to the authors thereof.

Division of Paleontology and Mineralogy.—Joint publication of the *Journal of Paleontology* by the Society of Economic Paleontologists and Mineralogists and the Paleontological Society was approved for a trial period of one year, and the sum of $500 was appropriated by the Association to help defray publication costs of the *Journal of Paleontology* and the *Journal of Sedimentary Petrology.*

Districts.—Boundaries of the Appalachian and New York districts were re-defined and steps toward formation of a European district were initiated.

Secretaries' conference, Washington, D. C.—The secretary was authorized to attend as an observer a conference of Secretaries of Engineering Societies, sponsored by the American Engineering Council, January 10, 1935. Report of this meeting has been made to members of the executive committee and headquarters office. Affiliation with the Council was considered, but deemed not desirable at this time.

Editorial assistance.—Editorial assistance and headquarters' office space were increased during the fall of 1934, in order that editorial work on special volumes and the *Bulletin* might proceed at a more rapid rate.

Annotated Bibliography of Economic Geology.—An appropriation of $250 was made to the National Research Council for use in preparation of abstracts and publication of the *Annotated Bibliography of Economic Geology.*

Committee on abstracts.—The president was authorized to appoint a committee of three to investigate the matter of preparation by the Association of abstracts of articles on petroleum geology and technology for publication in the *Bulletin*, and to consider arrangements for exchange of abstracts with other publications.

Coöperation with Association of American State Geologists.—It was recommended that the Association through its editorial staff coöperate with the Association of American State Geologists in the preparation of popular articles dealing with geological subjects and the importance of geology to the Commonwealth.

Estimation of California oil reserves.—The executive committee found no objection to the Pacific Section establishing a special committee to study and make estimates of the known petroleum reserves of that state as outlined in correspondence with officers of the Section.

Survey of unemployment.—Reports from district representatives indicated much improvement in employment conditions among petroleum geologists since adoption of the petroleum code of fair competition and consequential improvement in oil prices. The services of the Association and its executive committee have been offered to those in charge of federal relief work of a geological nature.

FINANCES

GENERAL

The Association experienced a very successful year financially during 1934. Advances in the value of bonds, payment of accounts receivable previously charged off, and continuation of conservative financial policies established during the preceding administrations resulted in giving a total net gain of $13,119 for the year, of which $10,659 belonged to the General Fund, $2,331 to the Publication Fund, and $129 to the Research Fund. The Geophysics Division and the Division of Paleontology and Mineralogy also reported satisfactory financial conditions at the close of 1934. Financial statements (except as to the inventory and investment accounts) published in the March, 1935, issue of the *Bulletin* give the detailed reports of audits of the Association and of its two Divisions. Financial summaries and comparisons for recent years and prospects for 1935 are submitted herewith in Tables IV–VIII.

ASSETS AND LIABILITIES

Successive audits published in the March issues of the *Bulletin* have shown the growth of the net assets of the Association. By the end of 1934 these had reached the substantial figure of almost $75,000, of which $20,150 is credited to the Publication Fund and $1,209 to the Research Fund (Exhibit A of Audit). Nearly 25 per cent of these assets are in the form of pub-

lications carried at a conservative inventory value. During normal years the Association derives considerable cash revenue from sales of these publications (Exhibit C of Audit). These inventories increased $2,949 during 1934. About 65 per cent of the assets are in bonds from which interest totaling $2,213 was received during 1934. In the auditing statements the bonds are carried at the lower figure of cost or current market value. The increase in bond values gave an accounting gain of $4,776 during 1934. However, the total advance in bond values was $5,517, several issues having advanced above cost. With the advice of the finance committee, the executive committee increased the net bond investment by about $7,600, making a total of nearly $16,000 of bonds purchased by the past two administrations. The cash on hand at the end of 1934 was $11,023.

REVENUES AND EXPENSES

The revenues and expenses for the past three years are summarized in Table IV. Expenditures have been listed in detail in audit reports printed in the March issues of the *Bulletin.*

General Fund.—Attention is called to two main sources of added income during 1934 as compared with 1933, these being $5,181 from sale of *Problems of Petroleum Geology* and $3,004 additional receipts from dues. Expenses were mainly affected by $6,270 expended on *Problems of Petroleum Geology* and $741 decrease in General and Administrative expenses. The publishers' charges for the *Bulletin* increased $1,438, due for the most part to the printing of 2,000 more copies of the *Bulletin* and 169 more pages of text than in 1933. As a result of printing more copies, the cost per copy remained 55 cents as during the previous year.

Publication Fund.—As no new publications were issued by this fund during the past year, revenues for the Publication Fund declined from $3,816 to $1,357. Advance expenditures on the *Geology of Natural Gas* volume totaled $1,652. The fund closed the year with a gain of $282 due to interest received in the amount of $572.

Research Fund.—The Research Fund was inactive during 1934, except as to $61 received as interest on investments.

BUDGET

Table IV includes estimates of revenues and expenses expected to accrue during 1935. Following the 1935 annual meeting, these figures have been adjusted to the new basis of dues of $10 for members, and $10, $8, and $6 for associates. Moderate surpluses are predicted for the General and Publication Funds. An expenditure by the Research Fund of less than $50 for a questionnaire is expected to be met by interest receipts during 1935.

Thanks are due all members of the executive and finance committees and the trustees of the Publication and Research Funds for careful attention and advice given to problems of financial administration of Assocation funds during the past year. The business manager and headquarters staff have rendered faithful and untiring service in behalf of the Association.

MONROE G. CHENEY, *secretary-treasurer*

TABLE I

Total Membership by Years

May 19, 1917	94	March 1, 1927	1,670
February 15, 1918	176	March 1, 1928	1,952
March 15, 1919	348	March 1, 1929	2,126
March 18, 1920	392	March 1, 1930	2,292
March 15, 1921	621	March 1, 1931	2,562
March 8, 1922	767	March 1, 1932	2,558
March 20, 1923	901	March 1, 1933	2,336
March 20, 1924	1,080	March 1, 1934	2,043
March 21, 1925	1,253	March 1, 1935	1,973
March 20, 1926	1,504		

TABLE II

Comparative Data of Membership

	March 1, 1934		*March 1, 1935*	
Number of honorary members	6		8	
Number of life members	2		2	
Number of members	1,634		1,591	
Number of associates	401		372	
Total number members and associates		2,043		1,973
Increase in membership		—		—
Decrease in membership		293		70
Applicants elected, dues unpaid	5		6	
Applicants approved for publication	11		23	
Recent applications	18		21	
Total applications on hand		34		50
Applications approved for transfer, dues unpaid	6		8	
Applications for transfer approved for publication	1		5	
Recent applications for transfer on hand	4		7	
Total applications for transfer on hand		11		20
Number of members and associates withdrawn	7		10	
Number of members and associates dropped	339		152	
Number of members and associates died	8		11	
Total loss in membership		354		173
Number of members and associates in arrears, previous year	332		184	
Members in arrears, current year	813		733	
Associates in arrears, current year	239		191	
Total number members and associates in arrears, current year		1,052		924
Total number members and associates in good standing		991		1,049

TABLE III

GEOGRAPHIC DISTRIBUTION OF MEMBERS

March 1, 1935

Arizona	2	Maine	1	Oklahoma	348
Arkansas	7	Maryland	3	Oregon	1
California	231	Massachusetts	9	Pennsylvania	44
Colorado	42	Michigan	16	S. Dakota	2
Connecticut	3	Minnesota	4	Tennessee	3
Delaware	1	Mississippi	7	Texas	636
Dist. of Columbia	25	Missouri	25	Utah	1
Florida	5	Montana	9	Virginia	1
Illinois	24	Nebraska	8	Washington	4
Indiana	4	New Jersey	6	W. Virginia	14
Iowa	4	New Mexico	13	Wisconsin	4
Kansas	76	New York	67	Wyoming	8
Kentucky	7	N. Carolina	1		
Louisiana	65	Ohio	6		

Total members in United States............1,737

Africa	4	Czechoslovakia	1	Palestine	1
Arabia	6	D. East Indies	11	Peru	2
Argentina	20	England	13	Poland	2
Australia	5	France	9	Roumania	3
Austria	4	Germany	10	Russia	2
Belgian Congo	1	Holland	15	Scotland	5
Brazil	2	Iraq	3	Spain	1
B. West Indies	6	Italy	2	Sweden	1
Canada	17	Japan	4	Switzerland	8
Colombia	7	Madagascar	2	Turkey	2
Cuba	3	Mexico	24	Venezuela	40

Total members in foreign countries......... 236

Grand total............................1,973

TABLE IV

ACCRUED INCOME AND EXPENSES 1932–1933–1934 AND BUDGET 1935

GENERAL FUND

	1932	1933	1934	1935 Estimated
REVENUES				
Operating Revenues:				
Publications:				
Bulletin:				
Subscriptions	$ 3,471	$ 3,339	$ 3,415	$ 3,400
Advertising	2,946	2,690	2,525	2,600
Membership—$6 each	11,064	10,332	10,602	10,800
Bound Volumes	2,276	1,712	1,677	1,800
Back Numbers	591	485	391	400
	$20,348	$18,558	$18,610	$19,000
Special Publications:				
Structure Vol. II	368	315	426	400
Problems of Petrol. Geol.			5,181	2,000
Index Alberta Symposium	122	60	22	25
	$ 490	$ 375	$ 5,629	$ 2,425

	1922	1933	1934	1935 Estimated
Other Revenues:				
Proportion Dues	16,434	9,292	9,514	6,600
Old Accts., charged off			2,510	500
Interest	1,568	1,513	1,580	1,700
Miscellaneous	18	53	82	50
	$18,020	$10,858	$13,686	$ 8,850
	$38,858	$29,791	$37,925	$30,275
EXPENSES				
Publications:				
Bulletin: et cetera	24,397	16,287	18,123	18,500
Problems of Petrol. Geol.			6,270	
General and Administrative	11,094	10,795	10,054	11,300
	35,491	27,082	34,447	29,800
Surplus	3,367	2,709	3,478	475

PUBLICATION FUND

REVENUES				
Operating Revenues				
Special Publications:				
Structure Vol. I	$ 292	$ 260	$ 411	$ 400
Geology of California	28	3,556	946	400
Geology of Natural Gas				4,500
	$ 320	$3,816	$1,357	$5,300
Other Revenues:				
Interest	589	634	572	750
Miscellaneous	—	—	5	—
Convention	1,283	—	—	—
	$1,872	$ 634	$ 577	$ 750
	$2,192	$4,450	$1,934	$6,050
EXPENSES				
Publications:				
Geology of California	—	$2,571	—	—
Geology of Natural Gas	—	—	$1,652	$5,600
		$2,571	$1,652	$5,600
Surplus	$2,192	$1,879	$ 282	$ 450

TABLE V

Comparison of Net Income by Years

	1932	1933	1934
Accrued Net Income	$41,437.71	$34,630.22	$39,893.96
Expenses:			
General and Administrative	11,094.11	10,795.38	10,053.92
Publication	24,397.43	18,998.41	24,445.83
Total	35,491.54	29,793.79	34,499.75
Excess Income over Expenses	5,946.17	4,836.43	5,394.21
Appreciation of Investments	−938.00	707.65	4,776.06

Inventory, Publications	−3,581.12	−1,900.00	2,948.84
Reserve for Sidney Powers Memorial Fund	—	167.50	—
Net Accrued Income, as per Audits	1,427.05	3,476.58	13,119.11
Distribution Net Accrued Income as per Audits:			
General Fund	792.19	−439.62	10,659.14
Publication Fund	841.19	3,581.92	2,331.45
Research Fund	−206.33	334.28	128.52

TABLE VI

COMPARISON OF COST OF BULLETIN

	1931	*1932*	*1933*	*1934*
Total Expenses	$33,129.01*	$25,008.17*	$16,974.87*	$18,213.19*
Monthly Edition	4,250– 4,100	3,700– 3,000	2,918– 2,412	2,845– 2,700
Total Copies Printed	49,350	38,947	31,068	33,096
Total Pages Printed, Including Covers	1,820	1,686	1,842	2,024
Total Pages of Text	1,476	1,378	1,568	1,737
Total Cost per Copy	0.67	0.64	0.55	0.55
Total Cost per Page for Total Printed	0.0044	0.0050	0.0038	0.0033
Total Cost per Page, Including Covers	18.20	14.83	9.22	9.00
Cost of Printing Only	19,425.74	14,718.84	7,773.95	8,589.11
Cost of Printing per Copy	0.3936	0.3779	0.2502	0.2595
Cost of Printing per Inside Page	10.96	8.98	4.33	4.46
Cost of Printing per Page Printed, Less Covers	0.0027	0.0029	0.0017	0.0016

* Including proportion clerical administrative expenses.

TABLE VII

INVESTMENTS

1932 Values	*Cost*	*Market Value End of Year*	*Depreciation*	*Per Cent Depreciation*
General Fund	$26,873.43	$18,205.98	$8,667.45	32.2
Life Membership Fund	613.30	579.55	33.75	5.5
Publication Fund	16,195.44	11,112.39	5,083.05	31.4
Research Fund	1,268.04	700.54	567.50	44.7
Totals	44,950.21	30,598.46	14,351.75	31.9
1933 Values				
General Fund	35,040.70	25,868.40	9,172.30	26.2
Life Membership Fund	629.44	604.44	25.00	3.9
Publication Fund	14,246.61	10,094.81	4,151.80	29.1
Research Fund	1,351.73	1,056.73	295.00	21.8
Totals	51,268.48	37,624.38	13,644.10	26.6

1934 Values				
General Fund	39,259.78*	34,340.73	5,517.32†	14.05
Publication Fund	16,374.91	13,517.77	3,123.22†	19.07
Research Fund	1,412.55	1,185.05	227.50	16.10
Totals	57,047.24	49,043.55	8,868.04	15.54

* Investment holdings of General Fund and Life Membership Fund, merged.
† At full market value, depreciation $4,919.05 and $2,857.14, respectively.

TABLE VIII

SPECIAL PUBLICATIONS

	Structure Vol. I	*Structure Vol. II*	*Geology Calif.*	*Prob. Petrol. Geology*	*Total*
Inventory, Dec. 31, 1933	$875.91	$2,451.60	$962.80	—	$4,290.31
Inventory, Dec. 31, 1934	669.31	2,181.60	589.63	$2,781.85	6,222.39
Sales, 1934	411.28	425.88	946.35	5,181.26	6,964.77
Cost of Sales	206.61	270.00	372.96	3,245.00	4,094.57
Gross Profit	204.67	155.88	573.39	1,936.26	2,870.20
Total edition	2,500	2,500	1,500	2,043	
Copies on Hand, Dec. 31, 1933	301	681	542	—	
Copies on Hand, Dec. 31, 1934	230	606	332	943	
Number of Pages	510	780	355	1,073	
Cost (Inventory)	$2.91	$3.60	$1.78	$2.95	
Selling Price When Issued	4.00	4.00	4.00	5.00	
Present Selling Price					
Members and Associates	5.00	5.00	5.00	5.00	
Non-Members	7.00	7.00	5.00	6.00	

EXHIBIT III. REPORT OF EDITOR

The statistical information concerning the *Bulletin* and the comparison for the past four years are given in the following tabulation.

PAGES IN BULLETIN, 1934

Total number of pages of majors	1,366
Total number of pages of minors	371
Total number of pages of majors and minors	1,737
Total number of Roman pages	222
Total number of pages in 1934	1,959
Total number of illustrations	390
Total number of major articles	63
Total number of minor articles	55
Estimated number of pages of illustrations	210

BULLETIN PAGES IN 1931–34

Year	*Majors*	*Minors*	*Roman*	*Majors and Minors*	*Total*
1931	1,114	408	280	1,522	1,802
1932	1,080	298	252	1,378	1,630
1933	1,180	388	226	1,568	1,794
1934	1,366	371	222	1,737	1,959

This review shows that the *Bulletin* was larger than for any of the previous years and that a greater proportion of it was devoted to major articles.

The editor wishes to repeat, and with increased emphasis, the plea for more manuscripts for the *Bulletin*. During the past two years we have used all the papers submitted by the members and approved by the editorial staff, with the number rejected extremely small. In addition, we have used all of those in three windfalls—from the International Geological Congress, and from excess papers for the book, *Geology of Natural Gas*, and the book, *Problems of Petroleum Geology*. At present, the *Bulletin* schedule is made up to and including the July issue which takes every manuscript that we can now absolutely depend on receiving, including several that will be presented at the Wichita meeting.

Unless the rate of productivity by the membership increases or we get contributions from some sources not now foreseen, some *Bulletin* issues during the coming year will consist of the brief statement, probably unbound, of "No Manuscripts, No Bulletin."

The editorial staff appreciates several suggestions as to how the contents of the *Bulletin* could be improved, but being practically without choice of papers can see no way to follow these suggestions. For example, the suggestion was made that the Bulletin was going too much to foreign and technical articles and that there should be more comprehensive and general papers on subjects nearer home. The criticism was justified and the suggestion good; but, in the absence of sufficient papers of the sort desired, the editorial staff was thankful to have the foreign and technical papers.

Concerning special publications: the book, *Geology of Natural Gas* should be out within a few months, and we should have John Muir's *Geology of the Tampico Embayment* off the press before the next convention.

L. C. SNIDER, *editor*

EXHIBIT IV. REPORT (MINUTES) OF GENERAL BUSINESS COMMITTEE

The meeting was called to order by Ed. W. Owen, chairman, 2:00 P.M., March 20, 1935, Allis Hotel, Wichita, Kansas. The following committee members were present.

Executive Committee: W. B. Heroy, Frank R. Clark, E. B. Hopkins, M. G. Cheney

Members-at-Large: Frank A. Morgan, E. DeGolyer, E. C. Moncrief, A. I. Levorsen, H. D. Miser

Division of Paleontology: Gayle Scott, Maynard P. White

Division of Geophysics: O. C. Lester, Jr., A. L. Selig represented by E. E. Rosaire

District Representatives:

Amarillo, J. D. Thompson
Appalachian, not represented
Canada, Theo. A. Link represented by J. M. Dawson
Capital, Arthur A. Baker
Dallas, Sam M. Aronson
East Oklahoma, R.T. Lyons, L. Murray Neumann
Fort Worth, H. B. Fuqua
Great Lakes, Frank W. DeWolf

Houston, Paul Weaver
Mexico, not represented
New Mexico, not represented
New York, not represented
Pacific Coast, Clarence B. Osborne represented by Frank A. Morgan
Rocky Mountains, C. E. Dobbin represented by J. Harlan Johnson
San Antonio, Joseph M. Dawson
Shreveport, not represented
South America, not represented
Southern Permian Basin, not represented
Tyler, E. A. Wendlandt represented by J. S. Hudnall
Wichita, E. A. Wyman represented by Edward A. Koester
Wichita Falls, not represented

1. *Minutes of previous meeting.*—It was moved, seconded, and carried that the reading of the minutes of the last meeting of the committee be omitted, as the minutes had been published in the *Bulletin*.

2. *Reading of reports of committees.*—It was moved, seconded, and carried that the following reports be read to the committee: (a) report of the committee on geologic names and correlations; (b) report of the research committee; (c) report of the committee on applications of geology.

3. *Report of committee on geologic names and correlations, Ira H. Cram, chairman.*—After reading of the report, it was moved, seconded, and carried, that the report be accepted, and referred to the general business meeting with the recommendation that it be not read but that it be published in the May, 1935, *Bulletin*.

4. *Report of research committee, Donald C. Barton, chairman.*—After reading of the report it was moved, seconded, and carried that the report be accepted, and referred to the general business meeting with the recommendation that it be not read but that it be published in the May, 1935, *Bulletin*.

5. *Report of committee on applications of geology, F. H. Lahee, chairman.*—After reading of the report it was moved, seconded, and carried that the report be accepted, and referred to the general business meeting with the recommendation that it be not read but that it be published in the May, 1935, *Bulletin*.

6. *Change in annual dues.*—It was moved, seconded, and adopted unanimously that recommendation of the executive committee be approved and submitted to vote of membership at the annual business meeting changing the first two sentences of Article I, Section 2, of the by-laws to read as follows, to be effective as of January 1, 1935.

The annual dues of members of the Association shall be ten dollars ($10.00). The annual dues of associates for not to exceed three years after election shall be six dollars ($6.00); for the second three-year period eight dollars ($8.00); thereafter, the annual dues of such associates shall be ten dollars ($10.00).

7. *Change of by-laws as to reinstatements.*—Resolution was proposed, seconded, and adopted that the general business committee recommend to the general business meeting the addition to Article II, Section 4, of the by-laws of the following paragraph.

In the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for non-payment of dues and who shall apply

for reinstatement, the executive committee is authorized, in its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency, provided the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the executive committee. Such member or associate shall not be entitled to receive the *Bulletin* for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

8. *Recommendation for appropriation to Division of Geophysics.*—A resolution proposed by E. E. Rosaire, representative of the Division of Geophysics, was adopted as follows.

Whereas, the Society of Petroleum Geophysicists finds difficulty in extending their membership because many prospective members, receiving the transactions of the Society in the *Bulletin* of the A.A.P.G., do not care to duplicate their payments for such transactions; and

Whereas, the Society of Petroleum Geophysicists is planning to initiate the separate publication of a suitable *Journal;*

Be it resolved, that the general business committee recommend to the executive committee of the A.A.P.G. that the Society of Petroleum Geophysicists receive a contribution of $250.00 for 1935, this payment to be contingent upon the initiation of publication of such a *Journal*, provided, however, that members or associates in good standing in the A.A.P.G. receive the privilege of subscribing to this *Journal* at a privileged rate of $4.00 per year.

The meeting of the general business committee adjourned at 5:20 P.M.

ED. W. OWEN, *chairman* MONROE G. CHENEY, *secretary*

EXHIBIT V. REPORT OF GEOLOGIC NAMES AND CORRELATIONS

During the past year the work of the committee was limited almost entirely to the study of certain papers presented to the Association for publication. Recommendations were made on 12 papers: 8 dealing with Oklahoma geology, 2 with Rocky Mountain geology, 1 with Texas geology, and 1 with general geology.

The committee has recommended to the executive committee that the Association publish a glossary of structural and related terms applying to petroleum geology; that a man be chosen as editor who shall have final authority and responsibility for the preparation of the volume; that he be furnished with the necessary paid secretarial help; that the necessary preliminary work of assembling the subject matter shall be done by members of this committee and other members of the Association under the direction of the chosen editor.

Four new members were added to the committee: M. C. Israelsky, John R. Reeves, W. A. Thomas and Allen C. Tester. In the untimely death of C. L. Dake the committee lost one of its most enthusiastic members.

IRA H. CRAM, *chairman*

EXHIBIT VI. REPORT OF RESEARCH COMMITTEE

The annual business meeting of the committee was held on Wednesday, March 21, 1934. It was voted to hold a joint meeting with the research committee of the American Petroleum Institute on the subject "Recovery of

Petroleum" during the International Petroleum Exposition at Tulsa, Oklahoma, May 12–19, 1934. The following subcommittee was appointed by the chairman to represent the research committee and the Association at the joint meeting: C. V. Millikan, chairman; R. S. Knappen, vice-chairman; A. W. McCoy, M. G. Cheney, and R. C. Moore. It was voted to endorse Mr. Plummer's project to take a census of research projects and problems being carried on by members of the Association, and to request authorization from the executive committee for the expenditure of not more than one hundred dollars ($100.00) of the Research Fund to defray the cost of circularizing the membership of the Association.

The annual dinner and round-table discussion were held that evening. A lively discussion was held on the primary topic, "Time of Migration of Petroleum with Special Reference to the Age of Petroliferous Structures, and to Levorsen's 'Studies in Paleogeology'."

The mid-year meeting of the committee was on Saturday, May 19, under the chairmanship of C. V. Millikan, with the coöperation of the research committee of the American Petroleum Institute, of the Tulsa Geological Society, the Stratigraphic Society of Tulsa, and the Oklahoma Geological Society, at the International Petroleum Exposition, Tulsa, Oklahoma. Mr. Millikan's report on the meeting is as follows.

> I am pleased to report a very interesting meeting of the Research Committee which was held last Saturday, May 19, 1934, at which time the topic, "Geological Changes in Petroleum Reservoirs Affecting Recovery," was discussed. The attendance was 42.
>
> We received written discussions from Dr. W. H. Twenhofel, Mr. C. T. Reistle, Mr. John G. Bartram, Mr. R. H. Fash, and Mr. John R. Suman. Dr. Twenhofel's discussion covered the development of primary and secondary porosity and permeability. He dwelt principally on secondary porosity and permeability which might change due to cementation or decementation and crystallization. Mr. Reistle's discussion concerned the deposition of paraffin within production formations. Mr. Bartram presented several examples of tight sands in deep wells and suggested that it might be due to metamorphism with depth. Mr. Fash, of the Fort Worth Laboratories, presented a discussion on possible deposition of salts, particularly carbonates, within porous reservoirs. Mr. Suman pointed out in his discussion of the unconsolidated sands of the Gulf Coast, that large withdrawals of sand might cause the intercalary shale to close up and pinch off the production. Each of these written discussions formed the basis of discussion from the floor and resulted in bringing out numerous interesting theories concerning probable, and possible, causes of changes in porosity and permeability in petroleum reservoirs which would affect recovery.
>
> This is a phase of geology and engineering which has been given very little attention by either geologists or engineers. I am sure those who attended the meeting obtained a better idea of the scope of the problem. I believe that the importance of this type of work will become more generally recognized and that it is a topic worthy of additional consideration by the research committee.

Progress was made on the project for a census of research by members of the Association. Work on the project was delayed by unavoidable circumstances. The questionnaire was sent out this spring and the replies are coming in, but no analysis of them has been made.

The committee during the year has done much work in attempting to instigate the formation of local research and/or discussion groups and to instigate local consideration of examples illustrating migration or non-migration of oil and gas within the local area in preparation for the coming annual round-table discussion of the committee. Various members of the committee spoke at meetings of many of the local societies. The vice-chairman of the

committee was particularly active in that regard, as his work called him into many districts.

Several local societies as a result appointed committees on the question of examples of migration or non-migration of oil, and many others held special meetings to discuss the problem.

A promising young discussion group was formed at Houston under the auspices of the committee and of the Houston Geological Society, and under the leadership of Mr. Levorsen. Some subject in the literature is assigned in advance and then the group spends a long evening in lively argument.

The activities of the members of the committee more or less in line of duty have been as follows, according to replies to the chairman's questionnaire.

M. G. Cheney worked on his old research problems without starting on any new one and led the Midland Geological Society in a discussion on the problem of migration and accumulation.

C. E. Dobbin has worked as chairman with a committee of the Rocky Mountain Association of Petroleum Geologists, on the problem of "Investigation on the Migration of Oil."

Robert H. Dott took over the chairmanship of the subcommittee on the geologic cross sections in the Mid-Continent in place of Mr. Levorsen who moved to Texas. He has endeavored to press the completion of the sections which have previously been promised, but without much success as yet. He has been unable to arouse active interest in the preparation of new sections or revising old ones, for the increasing tempo of oil activity is keeping all the local geologists too busy.

H. W. Hoots reports that his activities as a member of the research committee during 1934 are somewhat intangible. But in California, encouragement has been given to thought and discussion of general problems relating to the origin and migration of oil; but it is somewhat of a slow process, because some of the problems of stratigraphic correlation must be solved before some of the fields can be considered. One of the major problems in California geology is the establishment of standard sections, and with them bases for correlation for each major oil district. Definite progress is being made in establishing such sections for the San Joaquin Valley and the Coastal district. Belief is becoming current that several of our formational names must be discarded at least temporarily in favor of faunal zones, until the formational significance of the faunal zones is learned. Several California geologists (including H. W. Hoots) are giving much attention to the importance of unconformities and the general geologic history for much of southern California. He failed to mention his collaboration in the interesting study on the origin of the oil at Playa del Rey, the results of which were published in the February *Bulletin*.

F. H. Lahee's time in the first part of the year was taken up with editorial work on the volume *Problems of Petroleum Geology* and later in assistance to Henry Ley in his editorial work on the volume *Geology of Natural Gas*.

A. I. Levorsen did much promotion of the discussion of the problem of the migration and non-migration of oil, and promotion of local discussion groups, and extended his paleogeologic maps to include other counties.

Henry Ley reports that his work of the past two years has consisted mainly in research, which has led to some good ideas, and, he is afraid, to

some poor ideas. He also, of course, was completing his duties as editor and compiler of the volume *Geology of Natural Gas*. His research has been centered mainly on the mapping of the underground facies of the Gulf and Comanche Cretaceous in Texas. His isopach maps show the position of the Comanche synclinal axis in Pecan Gap time southwestward extension of the Sabine uplift far into Texas. He is beginning to believe that his Comanche synclinal axis skirts north of the north flank of the Sabine uplift, cuts southeast through the interior Louisiana salt basin, possibly to connect with the Iberian axis of Barton. The age of this axis he believes to be wholly post-Comanche and that of the Sabine uplift to be late or post-Comanche. The Sabine uplift formed in and arose from the deep part of the Comanche embayment.

He makes the comment that we can not progress in studies concerning genesis and migration without exceedingly precise knowledge of stratigraphy, that we should take formations of geologic systems that produce gas/or oil and trace them throughout their continental extent, and learn all possible concerning facies and the occurrence of the relationships of occurrence to facies. He has played with this idea for about five years, and there appear to be definite relationships. Specific basin regions should be studied. Some geologists believe that we know a great deal about the reservoir conditions in northeast Texas. Ley disagrees, finding in the literature and in oral discussion scarcely even knowledge of the problem, even in connection with the surface outcrops. Much more must be known about thinning of formations: is it condensed section, truncation, overlap, or what? But a critical knowledge of correlation of stratigraphic formations is fundamental for such studies. He adds:

> . . . it seems to me that the Humble Oil and Refining Company has been and is contributing more critical literature than any other major company. Something should be done to get something worth while from the other companies. Ellisor's recent Pecan Gap paper is great stuff.

L. C. Snider reports that he has done nothing in research beyond pursuing his general study of probable sources of new supply of petroleum sufficient to keep our domestic supply up to our probable consumption.

Parker D. Trask has devoted his entire time to studies of source beds in connection with his work for the United States Geological Survey and the American Petroleum Institute; during the year he published two reports on the results of that work.

R. C. Moore has been engaged in a coöperative attack on various problems in stratigraphy of Pennsylvanian and Permian rocks of the northern Mid-Continent.

D. C. Barton, in addition to his work as chairman of the committee, acted as co-editor with George Sawtelle on a "Gulf Coast Volume" which is to be a companion volume to the *Geology of Salt Dome Oil Fields*, and did considerable research on the physiography of the Gulf Coast and on the geologic variation of oil. A report on a hasty study of the variation of the mean character of the United States oils by age was published; a report on the Migration of Oil at Spindletop is being presented at the Wichita meeting; and detailed statistical study was made of the variation of the character of crude with depth and age in the Gulf Coast; this study is still in active progress.

F. B. Plummer supervised the issuance of the questionnaire regarding re-

search by members of the Association. But as the replies have just begun to come in, he has not yet had time to make any analysis of them. With the following associates, he has been engaged in the following research during the year: with R. King "Range of Ammonoides and Pennsylvanian Brachiopods with Especial Reference to the Extent and Correlation of the Uddenites Zone" (under grant from the Penrose Fund of the Geological Society of America); with R. B. Newcombe, "Permeability of Reservoir Rocks with Especial Reference to Acid Treatment"; with E. C. Sargent, "Waters, Temperatures, and Oils of the Serpentine Plugs"; with Sidon Harris and R. B. Newcombe, "Application of Oscillograph to Permeability of Mud Fluids."

Lester C. Uren has supervised research activities during the year including: a continuance of the study of conical drainage, an experimental study of pressure gradients around wells; a study of permeability of unconsolidated sands of various degrees of compaction, and to a limited extent, of the permeability of California reservoir rocks; the value of gravel for sand screening in oil wells.

In the business meeting of the research committee, March 20, 1935, the question of sponsoring a new volume of data papers on the origin and migration of oil was discussed. The consensus of opinion was against sponsoring a volume at this time, either as a reprint volume of papers from the *Bulletin* or as a symposium of new papers but the committee believes that the attempt should be made to get a series of papers for the *Bulletin* on these subjects.

Also the subject of bringing worth-while projects to the attention of the United States Bureau of Mines, United States Geological Survey, and United States Coast and Geodetic Survey was discussed in connection with the contingency that those bureaus may have a considerable allotment from the new P.W.A. funds, if the proposed bill is passed. A considerable number of projects were suggested and informally approved. The chairman and Mr. Plummer will probably be able to get other worth-while suggestions from the questionnaire of the census of research. The committee would be glad to receive suggestions for other worth-while projects, which it might recommend for consideration by those bureaus.

The committee adopted as the primary topic for the round-table discussion at the March meeting in 1936 the following subject: "The Relation of the Occurrence of Oil and Gas to the Changing Facies of Formations Throughout the Extent of the Formations."

DONALD C. BARTON, *chairman*

EXHIBIT VII. REPORT OF COMMITTEE ON APPLICATIONS OF GEOLOGY

This report will outline the activities of the committee on applications of geology from last March until February, 1935, inclusive. Those who are interested in our progress may consult pp. 708–11 of the Association *Bulletin* for May, 1934, where our report for 1933–1934 is printed.

During the year just passed we have accomplished much of value. Several of our fourteen members have been especially energetic and, usually as chairmen of subcommittees, have produced real results.

In California, E. K. Soper wrote:

The evening adult classes in geology which were started in several Los Angeles high schools here in 1933 are being conducted with much success. At the annual meeting of the Pacific Coast Section of the A.A.P.G., held in Los Angeles early in November,

the local committee on applications of geology prepared and placed on display in the hotel lobby where the convention was held two educational exhibits: (1) a representative collection of oil-well cores from all California fields, suitably labeled; and (2) a collection of colored geological cross sections illustrating the various types of geological structure favorable for the accumulation of commercial oil deposits. These exhibits attracted considerable attention and favorable comment, and were seen by the regular patrons of the hotel as well as by the members of the A.A.P.G. attending the convention. The exhibit was made possible through the courtesy and coöperation of the geological department of the Union Oil Company and Mr. Noble, assistant chief geologist of the Union Oil Company, is largely responsible for the success of the exhibit.

An interesting and valuable contribution to public instruction in petroleum geology was a talk called, "Keeping Black Gold in the Treasury," broadcast on May 13 over Station KPO at San Francisco. While this was not one of our own contributions, we should take note of it as an excellent method of educating the public.

From Denver, we have the following from A. E. Brainerd.

The main work which we have recently done in this division on applications of geology is talks given by members of the organization to various clubs and schools. Several such talks have been given, and we believe that, with a real campaign, we may be able to place physiography in the secondary schools here as one of the elective sciences.

Suggestions have been made and seriously considered to label sedimentary outcrops along some of our main transcontinental highways across the state. This, however, will involve considerable expense and will take time to carry out.

The campaign for funds for the U.S.G.S., which we instituted and carried out a year ago, and which we are following up this year, has been nation wide, and we believe has been a real stimulus to the profession throughout the country. It has started various geological organizations—government, state and local—working on projects that can not fail to help further the knowledge of the usefulness of our profession.

Carey Croneis wrote:

This year (1934) as director of the Hall of Science at A Century of Progress I have been able to continue my work of the last few seasons in attempting to bring geology to the attention of the layman. The petroleum geology section in the Hall of Science was probably as well attended this year as last, despite the fact that the total attendance at the Fair was considerably lower. In part this results from the fact that approximately 500,000 school children visited the exhibit under the guidance of their teachers and seemed to find it particularly instructive.

Another line of activity in which I have been engaged that may be of interest to the committee is the direction of the production of a series of geological movies. I have written the scenarios for these movies, which will appear under the sponsorship of the University of Chicago and which are produced by the Electrical Research Products Company, that is, the Erpi producers. This organization, which is a subsidiary of the Bell Telephone Company, has been charged with the production responsibilities of this program and the National Parks Service has made possible the photographing arrangements and has had a large part in financing the program. The Parks part of the work has been under the leadership of another member of the Association, Mr. Earl A. Trager. The first six films should be available sometime early in 1935.

Marvin Lee reported several activities in Kansas, which indicate growing use of geological advice for public benefit. Such include in particular a comprehensive study of surface and subsurface conditions for better maintenance of supplies of potable water. The Kansas Geological Society has a Public Relations Committee of which Lee is chairman. He wrote:

We have been of service in coöperative work being done by the U. S. Bureau of Mines with the State Board of Health investigating and suggesting remedies for the abatement of pollution by oil-field brines.

We have further coöperated in compiling a descriptive booklet to be used as a pre-convention announcement of the A.A.P.G. annual meeting, which gives many facts and geological information of interest to oil producers and others. In addition to mailing this to all A.A.P.G. members at the earliest date, it will be sent to all Senators and Representatives of the Kansas Legislature and our Senators and Representatives in Congress, to the principal oil trade journals, to the leading newspapers in Kansas, and several other states. We believe that this will be an educational pamphlet to be kept in the files of every person receiving it, and is just another way of keeping the public advised of the importance of geology.

From Missouri Dr. Buehler wrote:

We have demonstrated during the present drought the extreme value of geological data in furnishing water to stricken areas. Under CWA we had an active project of determining the glacial channels of north Missouri and making water studies in this connection. Also the work in south Missouri included tabulating data on various water horizons. This material had been visualized on maps before the drought struck us. We were able, through the use of these maps, to produce many fine wells, especially in north Missouri with a comparatively small force of geologists. The work has certainly given many of the officials of this state, as well as many of the residents, an understanding of what geology can do. We think it was a fine demonstration of the economic application of this science.

Frank Clark was active on the committee which had charge of preparation of a geological exhibit for the Petroleum Exposition held at Tulsa May 12–May 19, 1934. In addition to this exhibit which graphically illustrated many of the facts of petroleum geology, a lecture on the applications of geology was delivered by Russell S. Knappen before a group of engineering students and others at Tulsa University. I quote from Clark's letter, as follows.

The exhibit was almost wholly graphic and consisted of subsurface cross sections, models, photographs, and charts.

The theme of this exhibit was to show the practical applications of geology in its various fields of activity, as connected with the oil industry. In addition, we prepared and distributed a pamphlet entitled "Applications of Geology." The text of this pamphlet was an effort to bring to the attention of those visiting the exhibit the value and application of geology. Seventy-five hundred copies of this pamphlet were printed and it is estimated that 4,500 were distributed at the Exposition. Copies were also presented to the High School and some also to Christ King school.

Hal P. Bybee stated

that the geologists of San Angelo have actually installed an exhibit of rocks, minerals, fossils, oils and charts in a glass case in the Public Library which is located in the county court house in San Angelo.

In Dallas, as in the past 2 years, a committee was appointed by the Dallas Petroleum Geologists to prepare an exhibit for the Dallas State Fair, held in October. This committee included F. E. Heath (chairman of the Dallas Petroleum Geologists), J. M. Wilson, L. W. Orynski, F. H. Lahee, and H. B. Hill, chairman. Mr. Hill reported as follows.

It is my feeling that the exhibits this year, as in the past, have reflected credit to the local group and the mass of information presented, graphically and in pictures, has been reviewed with considerable interest by the public.

Upon the invitation of Alpha Kappa Psi Fraternity, F. H. Lahee lectured on December 3 to students of the School of Commerce of Southern Methodist University, on the subject of "The Oil Industry."

In San Antonio, Mr. Cooper wrote that,

(1) We are encouraging the addition of new material to our museum and library located at 525 Milam Building. Many new specimens have been added during the past year; also a number of bulletins, etc.

(2) We have provided speakers on several occasions to address various civic and scientific societies on geologic subjects.

(3) Our local society in coöperation with the committee on applications of geology sponsored an address by Dr. Pearce of the University of Texas, on "Tales That Dead Men Tell" to which the public was invited.

(4) We have made contact with and discussed the possibility of introducing some phase of elementary geology in the local schools, but at the present time this cannot be arranged.

From Houston, J. M. Vetter wrote:

We have made an effort during the past few months to create, through the Houston Geological Society, a mutual interest in the principles of geology, as applied to the oil industry and affiliated lines of industry. To this end we have encouraged an exchange of luncheon speakers and have invited outsiders to our programs. In addition articles of local interest have been prepared by some of our members for publication in local papers.

Plans have been laid for a geological exhibit at the Oil Exposition to be held in Houston during the early part of April. The attendance at this Exposition which increases each year, will afford a means of contacting a large number of people. It is anticipated that many of those attending the Exposition will be interested in geologic problems. For this reason we hope to have a local geologist available to answer questions.

During the course of this year, word was received from the National Better Business Bureau that the pamphlet, "Some Facts Concerning the Occurrence of Oil and Natural Gas," written by Lahee for educational purposes under the auspices of our committee, had been distributed not only to business men, but also to certain schools for use in elementary teaching of petroleum geology. This article has appeared in the *Oil Weekly*, the *Dallas News*, and The *Scientific Monthly*,[1] and in mimeographed form prepared by the National Better Business Bureau.

In closing I want again to state the purpose of this committee which came into being in 1932. This committee was organized for educational purposes, namely, to explain to the public—by talks, published papers, exhibits, etc.—how geology can be made to serve the public, and particularly how the petroleum industry may be served by this science. In other words, while it is entirely possible that an improved public understanding of the value of geology may indirectly lead to employment of more geologists, the real and vital object of the committee is to impart a clearer conception of the uses of geology. I would say that wider and more efficient application of geological principles should be the main sequel to our educational efforts.

In this connection I want to add that proper and wider educational efforts, such as we are undertaking, may help to thwart the insidious propaganda of unscrupulous persons who, through their extravagant claims in reference to oil-finding and big profits, endeavor to hoodwink the public; and these educational efforts may also enable the public better to recognize and discount the false and inaccurate statements which sometimes flare up in print.

F. H. LAHEE, *chairman*

[1] Vol. 38 (May, 1934), pp. 467–70.

EXHIBIT VIII. REPORT OF RESOLUTIONS COMMITTEE

Be it resolved, that we, members of The American Association of Petroleum Geologists, express our appreciation and thanks to all who have contributed to the success of the twentieth annual meeting in Wichita, Kansas, and particularly to the following.

1. To the City of Wichita and the Wichita Chamber of Commerce for their hospitable reception and courteous assistance.
2. To the Kansas Geological Society, and to E. C. Moncrief, chairman of the committee on general arrangements, for their splendid coöperation with the officers of the Association.
3. To the wives of the local geologists for their thoughtful arrangements for the entertainment of the visiting ladies.
4. To all Wichita hotels and the Wichita Club, and especially to the Allis Hotel and its management for sacrificing income-producing space,—for their courteous service and assistance.
5. To the newspapers of Wichita and to the several trade journals of the oil industry for their efficient handling of the news features of the convention.
6. To the Wichita Country Club for extending their facilities to our members and guests participating in the golf tournament for the Bostick cup.
7. To the management of the American Salt and Coal Company at Lyons, Kansas, for permission to inspect their mine and property.

Be it resolved, that these resolutions be included in the minutes of this meeting and that copies be sent to the individuals and organizations named.

HUGH D. MISER, *chairman* S. H. GESTER GAYLE SCOTT

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

CONSTITUTION AND BY-LAWS

(Adopted 1918 and amended 1921, 1922, 1923, 1925, 1927, 1928, 1929, 1930, 1932, 1933, and 1935)

CONSTITUTION

ARTICLE I. NAME

This Association shall be called "The American Association of Petroleum Geologists," incorporated under the laws of Colorado the 21st day of April, 1924, for a period of twenty (20) years.

ARTICLE II. OBJECT

The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous persons posing as petroleum geologists.

ARTICLE III. MEMBERSHIP

Members

SECTION 1. Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduateof an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions, whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.

Life Members

SECTION 2. The executive committee may grant life membership to menbers who have paid their dues and are otherwise qualified.

Associates

SECTION 3. Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.

The executive committee may advance to active membership, without the formality of application for such change, those associates who have, subsequent to election, fulfilled the requirements for active membership.

Election to Membership

SECTION 4. Every candidate for admission as a member or associate shall submit a formal application on an application form authorized by the executive committee, signed by him, and endorsed by not less than three members who are in good standing, stating his training and experience and such other facts as the executive committee shall from time to time prescribe. Provided the executive committee, after due consideration, shall judge that the applicant's qualifications meet the requirements of the constitution, they shall cause to be published in the *Bulletin* the applicant's name and the names of his sponsors. If, after at least thirty days have elapsed since such publication, no reason is presented why the applicant should not be admitted, he shall be deemed eligible to membership or to associate membership, as the case may be, and shall be notified of his election.

SECTION 5. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the entire *Bulletin* for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice of election has been mailed, the executive committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the current year, and until such written notice and card are received, he shall in no way be considered a member of the Association.

Honorary Members

SECTION 6. The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the

cause of petroleum geology. Honorary members shall not be required to pay dues.

ARTICLE IV. OFFICERS AND THEIR DUTIES

Officers

SECTION 1. The officers of the Association shall be a president, a vice-president, a secretary-treasurer, and an editor. These, together with the past president, shall constitute the executive committee and managers of the Association.

SECTION 2. The officers shall be elected annually from the Association at large by written ballot deposited in a locked ballot box by those members, present at the annual meeting, who have paid their current dues and are otherwise qualified under the constitution. Each candidate, when voted for as a candidate for the particular office for which he is nominated, shall be thereby automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidates for the executive committee for two years.

SECTION 3. No one shall hold the office of president for two consecutive years and no one shall hold any other office for more than two consecutive years except the editor who shall not hold office for more than six consecutive years.

Duties of Officers

SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, and shall delegate members to represent the Association. He may, at his option, serve on, and may be chairman of, any committee.

SECTION 5. The vice-president shall assume the office of president in case of a vacancy from any cause in that office and shall assume the duties of president in case of the absence or disability of the latter.

SECRETARY 6. The secretary-treasurer shall assume the duties of president in case of the absence of both the president and vice-president. He shall have charge of the financial affairs of the Association and shall annually submit reports as secretary-treasurer covering the fiscal year. He shall receive all funds of the Association, and, under the direction of the executive committee, shall disburse all funds of the Association. He shall cause an audit to be prepared annually by a public accountant at the expense of the Association. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Association funds. The amount of such bonds shall be set by the executive committee and the expense shall be borne by the Association. The funds of the Association shall be disbursed by check as authorized by the executive committee.

SECTION 7. The editor shall be in charge of editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the *Bulletin* and for special publications, and, with the approval of the executive committee, may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting in which they are elected.

ARTICLE V. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

Executive Committee

SECTION 1. The executive committee shall consist of the president, past president, vice-president, secretary-treasurer, and editor.

Meetings and Duties

SECTION 2. The executive committee shall meet immediately preceding the annual meeting and at the call of the president may hold meetings when and where thought advisable, to conduct the affairs of the Association. A joint meeting of the outgoing and incoming executive committees shall be held immediately after the close of the annual Association business meeting. Members of the executive committee may vote by proxy on matters which require a unanimous vote.

SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created giving to the trustees, appointed for such purpose such direction as to investments as seems desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE VI. MEETINGS

The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed, and officers for the ensuing year shall be elected.

ARTICLE VII. AMENDMENTS

Amendments to this constitution may be proposed by a resolution of the executive committee, by a constitutional committee appointed by the president, or in writing by any ten members of the Association. All such resolutions or proposals must be submitted at the annual meeting of the business committee of the Association as provided in the by-laws, and only the business committee shall make recommendations concerning proposal constitutional changes at the annual Association business meeting. If such recommendations by the business committee shall be favorably acted on at the annual Association business meeting, the secretary-treasurer shall arrange for a ballot of the membership by mail within thirty (30) days after said annual Association business meeting, and a majority vote of the ballots received within ninety

(90) days of their mailing shall be sufficient to amend. The legality of all amendments must be determined by the executive committee prior to balloting.

BY-LAWS

ARTICLE I. DUES

SECTION 1. The fiscal year of the Association shall correspond with the calendar year.

SECTION 2. The annual dues of members of the Association shall be ten dollars ($10.00). The annual dues of associates for not to exceed three years after election shall be six dollars ($6.00); for the second three-year period eight dollars ($8.00); thereafter, the annual dues of such associates shall be ten dollars ($10.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members or associates who shall fail to pay their annual dues by April first shall not receive copies of the April *Bulletin* or succeeding *Bulletins*, nor shall they be privileged to buy Association special publications at prices made to the membership, until such arrears are met.

SECTION 3. On the payment of three hundred dollars ($300.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues. The funds derived from this source shall be placed in a permanent investment, the income from which shall be devoted to the same purposes as the regular dues.

ARTICLE II. RESIGNATION—SUSPENSION—EXPULSION

SECTION 1. Any member or associate may resign from the Association at any time. Such resignation shall be in writing and shall be accepted by the executive committee, subject to the payment of all outstanding dues and obligations of the resigning member or associate.

SECTION 2. Any member or associate who is more than a year delinquent (in arrears) in payment of dues shall be suspended from the Association. Any delinquent or suspended member or associate, at his own option, may request in writing that he be dropped from the Association and such request shall be granted by the executive committee. Any member or associate more than two years in arrears shall be dropped from the Association. The time of payment of delinquent dues for either one year or two years may be extended by an unanimous vote of the executive committee.

SECTION 3. Any member or associate who resigns or is dropped under the provisions of sections 1 and 2 of this article ceases to have any rights in the Association and ceases to incur further indebtedness to the Association.

SECTION 4. Any person who has ceased to be a member or associate under Section 1 or Section 2 of this article may be reinstated by a unanimous vote of the executive committee subject to the payment of any outstanding dues and obligations which were incurred, prior to the date when he ceased to be a member or associate of the Association.

In the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for non-payment of dues and who shall apply for reinstatement, the executive committee is authorized,

in its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency, provided, the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the executive committee. Such member or associate shall not be entitled to receive the *Bulletin* for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

SECTION 5. Any member or associate who, after being granted a hearing by the executive committee, shall be found guilty of a violation of the code of ethics of this Association or shall be found guilty of a violation of the established principles of professional ethics, or shall be found guilty of having made a false or misleading statement in his application for membership in the Association, may be suspended or expelled from the Association by a unanimous vote of the executive committee. The decision of the executive committee in all matters pertaining to the interpretation and execution of the provisions of this section shall be final.

ARTICLE III. PUBLICATIONS

SECTION 1. The proceedings of the annual meeting and the papers presented at such meeting shall be published at the discretion of the executive committee in the Association *Bulletin* or in such other form as the executive committee may decide best meets the needs of the membership of the Association.

SECTION 2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge a copy of the *Bulletin* of the Association for that year.

SECTION 3. The executive committee may authorize the printing of special publications to be financed by the Association from its general, publication, or special funds and offered for sale to members and associates in good standing at not less than the cost of publication and distribution.

ARTICLE IV. REGIONAL SECTIONS, TECHNICAL DIVISIONS, AND AFFILIATED SOCIETIES

SECTION 1. Regional sections of the Association may be established provided the members of such sections are members of the Association and shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular annual meeting, an affirmative vote of two-thirds of the members present and voting being necessary for the establishment of such a section; and provided that the Association may revoke the charter of any regional section by a vote of two-thirds of the members present and voting at a regular annual meeting.

SECTION 2. Technical divisions may be established, provided the members interested shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular meeting, an affirmative vote of two-thirds of the membership present and voting being necessary for the establishment of such a division. In like manner, the Association may dissolve a division by an affirmative vote of two-thirds of the members present and voting at any annual meeting. A technical division may have its own officers, and it may have its own constitu-

tion and by-laws provided that, in the opinion of the executive committee, these do not conflict with the constitution and by-laws of the Association. The executive committee shall be empowered to make arrangements with the officers of the division for the conduct of the business of the division. A division may admit to affiliate membership in the division specially qualified persons who are not eligible to membership in the Association. Technical divisions may affiliate with other scientific societies, with the approval of the executive committee.

SECTION 3. Subject to the affirmative vote of two-thirds of the membership present and voting at an annual meeting, and with legal advice, the executive committee may arrange for the affiliation with the Association of duly organized groups or societies, which by object, aims, constitution, by-laws, or practice are developing the study of geology or petroleum technology. In like manner and with like advice, the executive committee may arrange conditions for dissolution of such affiliations. Affiliation with the Association need not prevent affiliation with other scientific societies. Members of affiliated societies who are not members of the Association, shall not have the privilege of advertising their affiliation with the Association on professional cards or otherwise.

ARTICLE V. DISTRICT REPRESENTATIVES

The executive committee shall cause to be elected district representatives from districts which it shall define by a local geographic grouping of the membership. Such districts shall be redesignated and redefined by the executive committee as often as seems advisable. Each district shall be entitled to one representative for each seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the executive committee. They shall hold office for two years, their term of office expiring at the close of the annual meeting.

ARTICLE VI. BUSINESS COMMITTEE

There shall be a business committee to act as a council and advisory board to the executive committee and the Association. This committee shall consist of the executive committee, not more than five members at large appointed by the president, two members elected by and from each technical division, and the district representatives. The president shall also appoint a chairman and a vice-chairman, but neither of these need be one of those otherwise constituting the business committee. The secretary-treasurer shall act as secretary of the business committee. If a district or technical representative is unable to be present at any meeting of the committee he may designate an alternate, who, in the case of a district representative, may or may not be a resident of the district he is asked to represent, and the alternate, on presentation of such a designation in writing, shall have the same powers and privileges as a regularly chosen representative. The business committee shall meet the day before the annual meeting at which all proposed changes in the constitution or by-laws shall be considered, all old and new business shall be discussed, and recommendations shall be voted for presentation at the annual meeting.

ARTICLE VII. AMENDMENTS

These by-laws may be amended by vote of three-fourths of the members present and voting at any annual meeting, provided that such changes shall have been recommended to the meeting by the business committee and provided that their legality shall be determined by the executive committee prior to publication.

DUES REDUCED

By vote of the Association in business meeting at Wichita, March 23, 1935, the annual dues of members have been reduced from $12.00 to $10.00. The annual dues of associates for not to exceed 3 years after election have been reduced from $8.00 to $6.00; for the second 3-year period $8.00; thereafter, the annual dues of such associates have been reduced from $12.00 to $10.00. Members and associates who have paid dues for 1935 in accordance with the previous rates will not receive a refund of any part of such payment, but they will be credited with a rebate of any such amount in making payment of dues for the year 1936.

REINSTATEMENTS

By vote of the Association in business meeting at Wichita, March 23, 1935, in the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for non-payment of dues and who shall apply for reinstatement, the executive committee is authorized, in its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency, provided, the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the executive committee. Such member or associate shall not be entitled to receive the *Bulletin* for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

A. Irving Levorsen, *chairman*, Houston, Texas
E. C. Moncrief, *secretary*, Wichita, Kansas
William B. Heroy, New York, N. Y.
Frank A. Morgan, Los Angeles, California
L. C. Snider, New York, N. Y.

GENERAL BUSINESS COMMITTEE

Sam M. Aronson (1936)
Arthur A. Baker (1936)
R. F. Baker (1937)
Roy M. Barnes (1937)
R. A. Birk (1936)
Ira H. Cram (1937)
E. F. Davis (1936)
Thornton Davis (1937)
Frank W. DeWolf (1937)
C. E. Dobbin (1937)
H. B. Fuqua (1937)
L. W. Henry (1937)
William B. Heroy (1936)
James W. Kisling, Jr. (1937)
A. I. Levorsen (1937)
Theodore A. Link (1937)
Gerald C. Maddox (1937)
E. C. Moncrief (1936)
James G. Montgomery, Jr. (1937)
Frank A. Morgan (1936)
L. Murray Neumann (1936)
Kenneth Dale Owen (1937)
G. W. Schneider (1937)
E. F. Shea (1937)
L. C. Snider (1936)
Clare J. Stafford (1937)
J. D. Thompson, Jr. (1936)
J. M. Vetter (1936)
Louis N. Waterfall (1937)
Neil H. Wills (1937)

RESEARCH COMMITTEE

Donald C. Barton (1936), *chairman*, Humble Oil and Refining Company, Houston, Texas

Harold W. Hoots (1936)
R. S. Knappen (1936)
W. C. Spooner (1936)
Parker D. Trask (1936)
M. G. Cheney (1937)
Robert H. Dott (1937)
K. C. Heald (1937)
F. H. Lahee (1937)
H. A. Ley (1937)
R. C. Moore (1937)
F. B. Plummer (1937)

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

R. S. Knappen (1937)

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

Ira H. Cram, *chairman*, Pure Oil Company, Tulsa, Oklahoma

John G. Bartram
M. G. Cheney
Alexander Deussen
B. F. Hake
G. D. Hanna
M. C. Israelsky
A. I. Levorsen
C. L. Moody
R. C. Moore
Ed. W. Owen
J. R. Reeves
Allen C. Tester
W. A. Thomas

TRUSTEES OF REVOLVING PUBLICATION FUND

Charles H. Row (1936)
Ralph D. Reed (1937)

TRUSTEES OF RESEARCH FUND

Robert H. Dott (1936)
G. C. Gester (1937)

FINANCE COMMITTEE

Joseph E. Pogue (1936)
E. DeGolyer (1937)

COMMITTEE ON APPLICATIONS OF GEOLOGY

F. H. Lahee, *chairman*, Box 2880, Dallas, Texas

William H. Atkinson
Arthur E. Brainerd
H. A. Buehler
Hal P. Bybee
Frank R. Clark
Herschel H. Cooper
Carey Croneis
H. B. Hill
Earl P. Hindes
Marvin Lee
S. E. Slipper
E. K. Soper
J. M. Vetter

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 761-765, 1 FIG.

Memorial

FRANK CARNEY

Dr. Frank Carney, professor of geology at Baylor University and a member of The American Association of Petroleum Geologists, died December 13, 1934, at his home in Waco, Texas. He is survived by his wife, Mary Ellen Keegan Carney, and their three daughters and two sons who mourn the loss of their truest and most sympathetic companion.

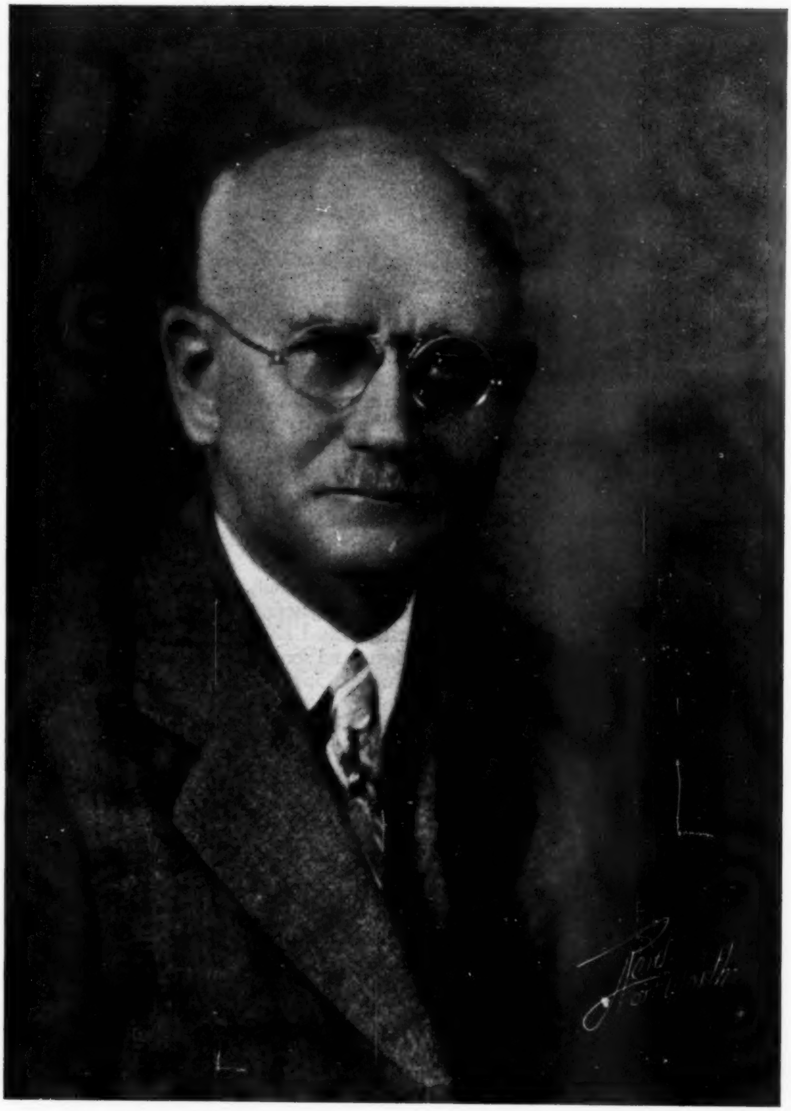
Frank Carney was born at Watkins, New York, March 15, 1868, son of Hugh and Esther R. Beahan Carney. As his father was a farmer and an unusual student of history and world politics, it was not strange that a son should decide to make teaching his life work while a pupil in district school. Frank prepared for college at Starkey Seminary, graduating in 1887, and remained in that institution as instructor in mathematics and history until 1891, when he entered Cornell University. After 3 years at Cornell, he returned to Starkey Seminary as principal and later joined the faculty of Keuka Institute. By attending summer sessions he completed his course at Cornell, receiving the A.B. degree. The degree of Doctor of Philosophy was granted him by Cornell in 1909. Through both preparatory school and college he was a self-supporting student, an accomplishment of which he was always proud. This was one reason why he especially enjoyed helping and encouraging those of his students who were working their way through college.

In 1904 Professor Carney went to Denison University, where he conducted an exceptional department of geology and geography for 13 years. During summers he taught at Cornell University, the University of Chicago, the State universities of Virginia and Michigan, and served as assistant geologist on the Ohio Geological Survey. It was during this time that he wrote most of his contributions to geography and geology.

In 1917 Carney accepted the position of chief geologist in charge of the geological and land departments of the National Refining Company. This work was done with his characteristic enthusiasm and thoroughness and these departments became and remained valuable assets to the company during his administration from 1917 to 1928.

During the winter of 1928–1929, Dr. Carney taught geography in Texas Christian University. From the fall of 1929 until his death he was head of the department of geology-geography in Baylor University. At Baylor he revived the department and caused it to grow until it was the largest science department in that institution, a department which was rapidly becoming known throughout the country.

He held membership in the following societies: Geological Society of America; Association of American Geographers (vice-president, 1915); American Association for the Advancement of Science; American Association of Petroleum Geologists; American Institute of Mining and Metallurgical Engineers; Seismological Society of America; Ohio Academy of Science (president, 1909); Michigan Academy of Science; Society of Economic Paleontologists and Mineralogists; Texas Academy of Science; C. L. Herrick Geological Society. He was a member of Phi Gamma Delta, Alpha Delta Tau, and Sigma Xi.



Frank Carney

Dr. Carney was a profound scholar, a great teacher, and a Christian gentleman in every true sense of the word; one who gave inspiration to all who knew him. His friendliness and his honest frankness made him a host of friends throughout this country and all of his students knew him as one to whom they could go for sound advice. His ability as a research scientist was shown by early work on glacial deposits of New York state and his discovery that there was evidence of more than one major advance of the ice. This was a revolutionary idea, contrary to the views of some of his professors, but an idea that found a sponsor in T. C. Chamberlin, who encouraged young Carney in his study and aided in publishing the discovery. Professor Carney's research extended into many phases of geography and geology and although it was interrupted during his commercial work he was able to resume these studies during his years at Baylor University. Field courses gave him opportunity to go to Brewster County, Texas, and to investigate thoroughly the deposits which Texas geologists had once considered glacial. Illness and death in December prevented the full presentation of the evidence at the meeting of the Geological Society of America at Rochester, although a published abstract summarizes his reasons for favoring glacial origin. Probably Frank Carney was more widely known as a speaker, for he was in great demand because of his clear presentation of subjects and because of a wealth of information on topics concerning geology, geography, education, world politics, and history, and because of his common sense in treating all sides of controversial matters. Students remember their professor as one of the really great teachers, for they had felt his presence in the classroom and they had eagerly absorbed his spirit and enthusiasm and loyalty and made them a part of themselves as they strove to learn the fundamentals of earth science. He was a born teacher. Although his courses were known as the hardest and credits were earned with difficulty, his classes always grew from year to year, more because of the personality of the man than the subject.

Dr. Raymond Moore, one of his students, pays the following tribute.

> Professor Frank Carney, was above all, the inspiring teacher. It is the special privilege and responsibility of such men to mold human lives, and it was as teacher that Doctor Carney made his greatest impression. This impression is not measured by physical developments of the department of geology under his hand, or by the number of students who were led to a life work in the science he loved, but rather by the intellectual qualities that he helped develop in a multitude of young men and women who sat in his classes. I was one of those youngsters at Denison who sought training under Doctor Carney not because of any interest in geology but because of report among students of the man himself. What he taught was incidental. But contact with such a teacher changed the entire objectives of my life. To measure the loss represented by the death of such a teacher, and to express adequately the sorrow brought by his death to those who, like myself, were the special inheritors of his spirit, is a task too great for words that can be written here.

BIBLIOGRAPHY OF FRANK CARNEY

1901

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NORMAN L. THOMAS

FORT WORTH, TEXAS
March 12, 1935.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 5 (MAY, 1935), PP. 766-768

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

A. K. TYSON, geologist with the Continental Oil Company, and formerly located at San Antonio, is now with the same company at 2405 Gulf Building, Houston, Texas.

T. K. KNOX has changed his address from Tower Petroleum Building, Dallas, to Saxet Gas Company, Shell Building, Houston, Texas.

D. A. HOLM, geologist with the Carter Oil Company, has been transferred from Ada, Oklahoma, to the Wichita, Kansas, office.

RICHARD V. HUGHES, formerly of Winchester, Kentucky, has accepted a position as assistant geologist with the Tropical Oil Company, Barranca-Bermeja, Colombia, S. A.

RUSSELL W. GRIMES geologist with the Shell Petroleum Corporation, has been transferred from St. Louis, Missouri, to Houston, Texas.

MORTON T. HIGGS is in charge of the Tulsa branch office of the Sperry-Sun Well Surveying Company.

R. G. GREENE formerly with the Schlumberger Well Surveying Corporation, is now in charge of geological work for the Bolsa Chica Oil Corporation, 707 Richfield Building, Los Angeles, California.

HARRY F. WRIGHT, geologist with Williams Brothers Well-Treating Company, and ROY L. GINTER of the Ginter Chemical Laboratory, both of Tulsa, are the authors of "Some Physical and Chemical Questions Relating to Acid Treatment of Oil Wells," in the March 21 issue of the *Oil and Gas Journal*.

A. L. ACKERS, geologist with the Stanolind Oil and Gas Company, has been transferred from Midland to Fort Worth, Texas.

E. GAIL CARPENTER and EARL G. LAY have organized the firm of Carpenter and Lay to engage in lease and royalty business, together with consulting practice with attention to microscopic work and the appraisal of oil and gas properties. The address of the new firm is 451 North Terrace Drive, Wichita, Kansas.

HAROLD F. MOSES, geologist with Carter Oil Company, has been transferred from Denver, Colorado, to Mount Pleasant, Michigan.

CLINTON ENGSTRAND, formerly with the Indian Territory Illuminating Oil Company, Bartlesville, Oklahoma, is now in the geological department of the Shell Petroleum Corporation, at Tulsa, Oklahoma.

EVERETT C. PARKER has changed his address from Wichita Falls, to 440 South Palm Street, Ponca City, Oklahoma.

ERNEST J. LEHNER, chief geologist for Trinidad Leaseholds, Ltd., at Point-a-Pierre, Trinidad, B. W. I., has severed his connection with that company and has taken up temporary residence at 38 Schtzengraben, Basel 3, Switzerland.

RUSSELL C. CONKLING, formerly with Shell Petroleum Corporation, has formed a partnership with J. L. GREENE, independent operator, at Midland, Texas. The address is Box 475.

JOHN M. VETTER, chief geologist for the Rio Bravo Oil Company, at Houston, Texas, has opened offices in the Second National Bank Building, where he will do consulting work. He will still retain his connection with the company.

E. B. WILSON, geologist, has been transferred from the Tyler to the San Angelo, Texas, office of the Sun Oil Company.

The following have been elected new officers of the Tulsa Stratigraphic Society: president, GLENN S. DILLE, of The Texas Company; vice-president, JOSEPH L. BORDEN, of The Pure Oil Company; and secretary-treasurer, R. E. MINNES, of The Tide Water Oil Company.

IAN CAMPBELL and JOHN H. MAXSON, of the Balch School of the Geological Sciences, California Institute of Technology, are authors of the following articles: "Geological Studies of the Archean Rocks at Grand Canyon," published in the *Carnegie Institution of Washington Year Book 33* issued in December, 1934; and "Archean Ripple Marks in the Grand Canyon," published in the *American Journal of Science* of October, 1934.

JOHN H. MAXSON and GEORGE H. ANDERSON have an article "Terminology of Surface Forms of the Erosion Cycle," in the *Journal of Geology* of January–February, 1935.

WALLACE E. PRATT, vice-president of the Humble Oil and Refining Company, Houston, Texas, spoke on "Oil Production—Its Development and Stabilization" at a public meeting of the United States Chamber of Commerce dealing with the problems of the natural resources industries. The meeting was held on May 1 in the United States Chamber of Commerce Building, Washington, D. C.

G. R. V. GRIFFITH, formerly engineer for the Associated Producers Company and later with the United States Geological Survey at Tulsa is now associated with the Morgan Petroleum Engineering Company at Wichita, Kansas.

EDWARD A. KOESTER is with the Darby Petroleum Corporation at Wichita, Kansas.

BORIS V. LERCKE has opened an office for examination of drill cuttings and consulting geological work in the Union National Bank Building, Wichita, Kansas.

The following district representatives have been elected for the new two-year term, ending with the annual meeting of March, 1937: Amarillo, Texas,

J. D. THOMPSON, JR.; Appalachian, JAMES G. MONTGOMERY, JR.; Oil City, Pennsylvania; Canada, THEODORE A. LINK, Calgary, Alberta; East Oklahoma, IRA H. CRAM and E. F. SHEA, Tulsa; Fort Worth, Texas, H. B. FUQUA; Great Lakes, FRANK W. DEWOLF, Urbana, Illinois; New Mexico, NEIL H. WILLS, Roswell; New York, R. F. BAKER, New York City; Pacific Coast, ROY M. BARNES and LOUIS N. WATERFALL, Los Angeles, California; Rocky Mountains, C. E. DOBBIN, Denver, Colorado; San Antonio, Texas, THORNTON DAVIS; Shreveport, Louisiana, GEORGE W. SCHNEIDER; South America, L. W. HENRY, Maracaibo, Venezuela; West Oklahoma, GERALD C. MADDOX, Oklahoma City; Wichita, CLARE J. STAFFORD, Wichita, Kansas.

Listed on the program of the annual meeting of the Eastern District of the Division of Production of the American Petroleum Institute to be held on June 5 and 6 at the William Penn Hotel, Pittsburgh, Pennsylvania, are the following papers: "Is There any Future for the Now-Drilled Eastern Oil Production under Natural or Standard Producing Methods," by P. H. CURRY of the South Penn Oil Company; "Symposium on Details of Oil and Gas Recovery by Artificial Means and the Practical Factors Determining the Possibility of Applying Artificial Recovery Methods to Oil or Gas Properties," by H. R. PIERCE, consulting engineer, *et al.;* "Latest Methods of Pumping Oil, Including Equipment," by J. C. ASKAM, of the Ohio Oil Company; "The Mechanics and Economic Success of the Acid Treatment of Oil and Gas-Bearing Formations; also a Summary of Oil and Gas Developments in Michigan Including Rotary Drilling," by R. B. NEWCOMBE, of the Michigan State Geological Survey; "Past Experiences and Future Possibilities of Detecting Subsurface Structures in Eastern Oil and Gas Fields," by FRANK M. BREWSTER, of the Belmont Quadrangle Drilling Corporation; "Latest Methods of Plugging Off Permeable Lenses of Saturated or Barren Sands in Water Flooding, Gas Repressuring, Gas Storage Reservoirs, Including the Possibilities of Permanent Plugging of Abandoned Oil and Gas Wells," by C. P. PARSONS, of the Halliburton Oil and Gas Cementing Company. J. H. NEWLON, 435 Sixth Avenue, Pittsburgh, is chairman of the Production Division of the District, and chairman of the committee on arrangements.

The fifth annual meeting of the Field Conference of Pennsylvania Geologists will have its headquarters at the Academy of Natural Sciences in Philadelphia, May 31–June 2. EDWARD H. WATSON, Bryn Mawr College, is chairman, and SAMUEL G. GORDON, of the Academy of Natural Sciences of Philadelphia, is secretary.

The executive committee has accepted the invitation of the Tulsa Geological Society and the Tulsa Chamber of Commerce to hold the twenty-first annual meeting of the Association at Tulsa, in March, 1936. Details will be published later.

New advertisers in this issue of the *Bulletin* are: Sperry-Sun Well Surveying Company (page iv), E. Leitz, Inc. (page v), Alexander Anderson, Inc. (page xvii), Western Geophysical Company (page xxi), Wm. M. Barret, Inc. (page xxiv).

A new advertiser in the *Bulletin* this year is Edgar Tobin Aerial Surveys, (page xx).